KANSAS USTILAGINEÆ

A Study of
the Kansas Smuts
especially with regard to
Germination

J. B. S. Norton
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Kansas Ustilaginaceae.

The smuts are among the most important fungi to man, economically. Millions of dollars are lost annually on account of their ravages among the cultivated crops. The study of their life history has been of great material value to agriculture in providing means of prevention.

To science this group is also of interest from its peculiar position in the system of fungi, and because of the lack of knowledge relating to it and the difficulty of studying it, especially certain parts of the life history. Although several prominent botanists have put the better part of their efforts into the study of this order, the smuts offer a vast store of knowledge yet unexplored.

About twenty genera of the Ustilaginal stock been distinguished, Magnus having recently added one and Brefeld two. These are separated principally on the manner of production, aggregation, and germination of the spores.

Briefly the life history is as follows. The spores germinate in water or other liquids, producing a tube which is an elongation of the inner wall of the spore which, increasing in size by taking up water, breaks through the outer wall, or perhaps sometimes passes through a "germ pore" in this wall. This tube is called the promycelium, is usually limited in length, and with a supply of nutrient material in the water, or to some extent in water alone, buds off conidia at the end or sides. These conidia may go on budding off.

Other conidia indefinitely in the manner of yeast. Fusions of the conidia and unions of different cells in various ways are found in many of the species.

When the supply of moisture is limited the promycelium or conidia that have been produced grow out into long "germ tubes", usually septate and the protoplasm following the end. Often long chains of conidia are produced in the air.

These germ tubes penetrate the young tissues of the host plant, usually in the early part of its life. The mycelium develops from this and grows throughout the host, finally producing its spores in the tissues of the host plant, usually in the ovaries or some part of the inflorescence.

The Ustilagineae in Kansas are represented by the

genera Ustilago, Tilletia, Entyloma, Sorosporium, Urocystis and Doassansia. The above genera are arranged in order of their number of representing species in the state. Far the greater number of our thirty three species belong to the genus Ustilago.

Scarcely enough data have been collected to show much regarding the distribution in the state. I have given the localities known except when the species is a very common one. Almost no work has been done on the smuts of the state, or any other fungi for that matter, except by the botanists of this College and Mr. Elam Bartholomew of Rooks Co. Almost all the species we have are from Riley and Rooks counties. I have endeavored to obtain some information from other institutions of the state but they give little or no attention to this phase of

botany.

A few words in explanation of the methods of research, etc., in these studies will be necessary. The study has been primarily the germination. The list has also been arranged to show what species are known to occur in the state and something of their distribution. Other observations of more or less interest and importance have been included, especially the effect of the fungus on the host plants.

In the limited time that has been put on the subject, scarcely a beginning could be made, and the principal thing learned in this spring's studies is that there remains a great amount of work yet to be done before the subject I have taken up can be called anything like complete.

The advantages offered by the excellent collection of Ustil-

agineae in the College herbarium, and the Station library abounding in works on smuts are almost as good as I could wish for.

The material used for germination I have collected mostly about Manhattan during the last two years.

The germination cultures have for the most part been made in hanging drop cultures. A drop of the culture medium is put on the lower side of a cover glass sealed with vasiline to the top of a chamber formed by gluing a glass ring to an ordinary microscope slide. This minature damp chamber allows the necessary air for germination, prevents evaporation, and at the same time the culture may easily be observed with the microscope. The cultures were kept in a large moist chamber to keep a more equal temperature and supply of moisture.

The temperature of the room has not varied much from 70° F.

Cultures of most of the smuts have been made both in water and in the modified Corn solution[1] used by Kellerman and Swingle for the same purpose. Usually check cultures of corn smut were made with the others in order to detect anything wrong in them. The corn smut being common and its germination well known it was well adapted to be used as a standard.

The most of the drawings have been made with a magnification of 1000 diameters given by a 2 mm oil immersion objective and 6 ocular with a Zeiss microscope, tube length 14, and an Abbe camera lucida. The drawings have been rather carefully made and are not intended simply to illustrate the written work, but to be equally prominent with it. Indeed they may show more

[1] 2nd Ann. Report, Kans. Exp. Sta. p. 230.

than I have attempted to write.

The nomenclature and synonomy I have not worked out to any great extent, and the list is not arranged exactly according to any system. The names used are mostly those used by Saccardo in his Sylloge Fungorum, and the arrangement is much the same, with the newer species added at the end.

I have not considered it necessary to give descriptions of the species or to give germination studies of other investigators when I have not repeated them myself.

Ustilagineae.

I. Ustilago.

1. U. Sorghi (Link.) Pass. Thüm. Herb. Mye. Oec. n. 63. (Plate II. fig. 1-5.)

Common on species of cultivated Sorghum; on Kaffir corn, Manhattan (Kellerman); on broomcorn, Philipsburg; also reported from other places on the latter.

The spores germinate in water in a few hours, produce promycelia 20-35 μ long and about 6 μ wide. In many cases where the water supply was not so abundant, long germ tubes narrower than the promycelium were produced, 500 or more μ long, the protoplasm following the end and the remainder of the tube divided by septa into cells about three diameters long. Knee joints occur in abundance and a few bow joints. Conidia few.

In modified Cohn solution

each germinated spore is soon surrounded by a mass of extensively branched promycelia bearing many conidia. No germtubes or fusions until the solution becomes exhausted, then long threads grow out from the promycelia, and from the conidia.

2. U. Ischaemi, Fuck. Enum. Fung. Nass. p. 22.

In the deformed inflorescence of Andropogon furcatus. The stems are shortened and the smutted flowers enclosed in the upper leaf sheath.

I have not tried germinating the spores as all my material is several years old. The specimens are from Mr. Bartholomew, of Rooks Co. He says the smut is undoubtedly perennial. Figures of the germination are given in Brefeld, Untersuchung. V p. 96. t. II. fig. 1-2.

3. U. austro-americana, Syd. Fungi

argentina IV, n. 45. (Plate I, fig. 10-13)

Forming large hard masses in the inflorescence of Polygonum Pennsylvanicum, Ribes and Republic coultiers.

The germination in water begins after a day or two and proceeds slowly. The promycelia are frequently branched and irregular. Conidia few.

4. U. Avenae, (Pers.) Jensen, Le Charbon des Céréales. p. 4.

Common on Oats.

The germination of this species and the other smut grain smuts (U. Levis, U. Hordei, U. nuda, and U. Tritici.) have been quite fully studied and described by Kellerman and Swingle in the Second Annual Report of the Kansas Experiment Station.

5. U. Levis. (K. & S.). Magnus, Ust. Provinz. Brandenburg. p. 69.

Also on oats but not so

common as the above.

6. U. Hordei, (Pers.) K. & S. 2nd. ann. Rept. Kans. Exp. Sta.
On Barley, Manhattan.

7. U. nuda, (Jensen) K. & S. 2nd Ann. Rept. Kans. Exp. Sta.
On Barley, Coolidge.

8. U. Tritici, (Pers.) Jensen, 2nd Ann. Rept. Kansas Exp. Sta.
On wheat, common all over the state.

9. U. Aristidae, Peck, Bull. Tor. Bot. Club. XII. p. 35. (Plate I. fig. 1-5.).
On Aristida (purpurea?). Hodgman and Ellis Counties. The smut fills the ovaries, and the awns are much shorter than usual, sometimes almost absent.
Germination in water begins almost immediately. After four hours a promycelium 10-12 μ long was produced. This grows rapidly for 8 or 10 hours

until 30-40 μ long. Then a conidium is formed at the end, three or four septa appear in the promycelium, and a part of the protoplasm in each cell thus formed passes into a conidium at its upper end, leaving a vacuole at the end next the spore. The conidia soon become detached.

In modified Cohn solution the germination is very similar, but slower and more vigorous.

10. U. Spermophora, Burr. and Curt. Curt. cat. p. 123.

On Eragrostis major, Riley county.

Attempts at germination unsuccessful.

11. U. Vilfae, Wint. Bull Tor. Bot. Club. X. p. 7.

On Sporobolus vaginiflorus. Cultures of spores failed to germinate.

12. U. Rabenhorstiana, Kühn, Hedwigia, 1876. p. 4. (Plate IV. fig 7-9.).

Common in the inflorescence of Panicum sanguinale. Every head on the smutted plants is usually smutted, a good evidence of early infection. The smut dwarfs the host plant and causes it to branch more than normally.

Growth vigorous and irregular in modified Cohn solution. No conidia. No germination in water.

This species has been confused in Kansas with U. Crusgalli. The spores are larger, thicker walled and olive brown, and much more pulverulent in the mass of spores.

13. U. Reiliana, Kühn, Rabenh. Fungi Europæi, no. 1998. (Plate I, fig. 14-18).

On Sorghum sp. Manhattan. On Zea Mays, Riley, Morris, Saline, Geary, and Jewell Counties. Rather common.

I have already described

The general appearance and the effect on the host plant in a note in the Botanical Gazette, October, 1895.

Germination after 24 hours in water. The promycelium is medium sized, grows little and bears few conidia.

In modified Cohn Solution germination takes place after two or three days. The promycelium is almost as wide as the spore at the base, and bears large yeast like colonies of conidia. The conidia are short and oval.

The spores are aggregated in masses and this species seems to be a good Sorosporium, but until further study of the development I have left it here.

14. U. neglecta. Niessl. Rab. Fung. Europ. no. 1200.

On Aelania glauca, Manhattan. The smut does not affect the outward appearance of the

host plant except to slightly enlarge the grains.

Attempted germination unsuccessful.

15. U. Mays Zeae (DC.) Magnus, Nat. Prov. Brandenb. p. 70. (Plate II, fig. 6-13).

Common everywhere on all parts of the corn Plant (Zea mays).

Germination in water begins in 18-24 hours. The promycelium is three or four celled and often bears numerous conidia, usually two to four. The conidia are fusiform and usually easily detached. The whole promycelium is often detached a short distance from the spore in a few hours after production. Air conidia are abundant in dryer cultures.

16. U. Cesatii. Fisch. de Wald. Aperçu. p. 25.

In the greatly enlarged ovaries or the whole inflorescence of Cus-

Chrys Tribuloides, all over the state, (Plate III. fig. 11-13.); Panicum capillare, Manhattan, (Plate I, fig. 14-17); P. proliferum, Manhattan, (Plate III. fig. 8-10, Plate II. fig. 3-4); Andropogon scoparius, Manhattan (Plate I, fig. 6-8).

The stems of the host plant are shortened and the enlarged ovaries project or are enclosed by the upper leaf. If the plant is not badly affected the glumes and other floral organs grow out into long leaf like bodies, sometimes two or three inches long.

The germination in water is difficult. In ten or fifteen cultures in water only a few spores germinated. The germination in Modified Cohn Solution takes place in one or two days, almost always sooner than it does in water.

The promycelium is usually a simple and often branching tube but of no very great length. Sometimes it is short and may then

produce a few conidia, which are short and oblong. Germ tubes are frequent, and some fusions between adjoining cells take place.

It is very probable that further study may make two or even three species out of this, but for the present I have placed them together. The germination of the spores from different host plants is different; but enough cultures have not yet been made to establish any thing as constant.

17. U. Ulmiculosa (Mass.) Jul. Nat. p. 102.
On Polygonum acre, Rooks and Riley counties, and P. Pennsylvanicum, Riley.
Repeated attempts at germination unsuccessful.

18. U. Andropogonis Kell. and Swing. Jour. Myc. 1889, p. 12. (Plate III, fig. 14-17).
Common on Andropogon furcatus, from several places in

the stalk. On Andropogon Hallii, Arkalon and Harper.

The smut causes the host plant to flower several weeks earlier than it normally does, and the affected plants are about half as high as the healthy ones.

No germination in water. In Modified Cohn solution the spores germinate after two or three days, but produce only an undivided and unbranched tube, and of moderate length. No conidia. Two years ago some germinated well in manure solution and produced abundant short thick conidia.

19. U. Bouteloua, Kell. and Swing. Jour Myc. 1889. p. 12. (not figured)

In ovaries of Bouteloua oligostachya, Rooks and Riley Counties.

Germinates in water in about 12 hours. A short promycelium is produced in a few hours and

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soon bears a small conidium on the end and then a few lateral ones. The conidia are short and sometimes stalked. It may be that several conidia are produced in turn from the same point on the promycelium, as numerous conidia were floating in the water near budding promycelia.

20. U. pustulata Tracy and Earle, Bull. For. Bot. Club, 1895, p. 170.

On Panicum proliferum, Pottawatomie Co. (T.T. Crevecoeur).

Attempted germination was unsuccessful.

21. U. filamenta. n.s. (Plate V. fig. 1, 2, 4-6, Plate VI, fig. 1, Plate VII, fig 1-4)

On Bouteloua racemosa and oligostachya, Riley and Wabaunsee Co-unties.

Producing rounded protruding swellings ½-2 mm wide and 1-12 mm long on the leaves and sometimes stems of the host plant. Spore mass irregular-

by angled, sub-globose, dark yellowish brown, rather opaque, black in mass, minutely echinulate, contents granular, 13 x 15 μ in diameter.

The germination in water in favorable cases begins in about 12 hours. The usual manner is to form long septate tubes (about 300 μ long, the cells 2-3 μ x 6-10 μ) which grow rapidly in length for two or three days, these produce a few conidia and usually branch some. The branches near the edge have a tendency to grow backward in a peculiar manner.

In nutrient solutions more abundant conidia are produced. These vary from fusiform to almost spherical. Chains of air conidia were sometimes seen. These conidia vary in length like the others but are usually shorter. The conidia are at first smaller at the apex, they bud off secondary conidia at the end grow longer and fuller,

and finally become septate, the whole chain of conidia forming a long irregular branch of short thick cells bearing small conidia at the sides. (Fig. 9, Plate I). In old cultures some of these cells become enlarged and rounded as if they were attempting to form teleutospores.

The smut has been found well developed the last of April and is probably perennial in the underground parts of the host. Pustules have been found on the leaves just emerging from the ground. The affected plants scarcely ever send up flower stems but when they do the smut may occur in some of the flowers or at the base of the spikelets.

22. U. minor, n.s. (Plate V fig. 3, IV, fig. 2 VI fig. 5).

On leaves of Bouteloua hirsuta.

Manhattan, rare.

Much like the preceding, but spores much smaller (8–9 μ). Contents

less homogeneous, pustules on host plant fewer and larger.

On account of lack of fresh material none of the spores germinated in my cultures this spring. From the few that were germinated two years ago, the germination seems to be about the same as U. filamenta

I have examined a great number of the three species of Bouteloua growing together here, where B. oligostachya and racemosa were much smutted, and in almost every case hirsuta was free from smut.

II. Tilletia.

23. T. fortans (B. & C.) Schroet. Beitr. Biol. Pfl. 1877, p. 345.

Common on Wheat (Triticum sp.).

A few spores of this and the next germinated in water after about a week. Conidia produced fasciculate on the end of the promycelium.

24. T. Tritica. (Bjerk.) Wint. Die Pilze.
On Wheat (Triticum sp.) Rocks and Grady counties.

25. T. Buchloeana, K. & S. Jour. Myc. V, p. 11.
In ovaries in the normally staminate spikelets of Buchloe dactyloides. Jewell Co. (miss Dahl), Fargo and Ford counties (Kellerman and Swingle).

In the early part of last year while making some germination tests preliminary to infection experiments with corn smut, a culture of T. Buchloeana was made on a glass slide in a moist chamber, from material collected in Jewell Co. the previous summer. This year I have not succeeded in getting the same material to germinate. Unfortunately no drawings of the first were made and only the following note, "After 9 days. Germination good some show the characteristic conidia of Tilletia."

26. T. rotundata, Ell. & E.

Collected this year in ovaries of Panicum virgatum, Manhattan, and on herbarium specimen collected by Joseph Henry at Salina in 1886

Attempted germination unsuccessful.

III Entyloma

Owing to lack of suitable fresh material no germination studies of this genus were made.

27. E. Compositarum, Farlow. Crypt. Fl. White Mount. p. 238.

On leaves of Ambrosia psilostachya, Riley and Cloud counties; Bidens Chrysanthemoides, Rooks Co.; Heterotheca Lamarckii, Rooks Co.; Senecio Balsamitae, Riley.

28. E. Menispermi, Farl. and Trel. Bot. Gaz. 1883. Aug. p. 5.

Common on leaves of Menispermum Canadense.

29. E. Physalidis (Kolshbr. & Cooke) Wint.
Hedwigia, 1883, p. 130, and 1887, p. 8.
On Solanum nigrum, Riley Co.; Physalis pubescens, Riley Co.; P. longifolia, Rooks and Riley Counties. Probably on other Solanaceae in the state

IV Doassansiea.

I have not accurately identified the material we have of this genus, and having no fresh specimens I have not attempted germination.

30. D. Alismatis (Nees.) Cornu. Ann. Sci. Nat. Ser. VI. Tom XV, (1883) p. 285.
On Alisma Plantago, Rooks and Saline Counties; and on Sagittaria variabilis, Riley Co.
The one on the last host may be D. Sagittariae.(1)

(1) A Doassansia on Potamogeton is reported from Lawrence by Mr. M. A. Barber of the State University, probably D. occulta

V. Sorosporium.

31. S. album. Peck, Bot. Gaz. 1880, p. 30.
On Carex Pennsylvanica. Found at Manhattan by Mr. J. E. Payne in 1894.
Germination unsuccessful.

32. S. cuneatum Schofield, 2nd Edit. Withers Appx. Cat. Flora. Neb. (Plate IV, fig. 5, 6).
In enlarged stems and contracted inflorescence of Solidago Missouriensis, Rooks Co. and on old weathered specimens of Solidago sp. Manhattan.
Germination in water begins in 12 hours, More or less branched tubes pointed at the ends and septate, a few conidia and in dry cultures long chains of air conidia are produced.

VI. Urocystis

33. U. Anemonis. (Pers.) Schroet. Beitr. Biol.

Pfl. 1877, p. 375.

On leaves of Anemone Caroliniana. Rooks Co. (Bartholomew)

No material for germination.

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Kellerman - Smuts of Farm Crops.
Kellerman and Swingle - Reports and Bulletins, Kansas Experiment Station.
Brefeld - Untersuchungen über die Brand-Pilze, and other Papers.
Fischer de Waldheim - Various papers on Ustilagineae
Kühn - Papers on Smuts.
Winter - Die Pilze.
Plowright - British Uredineae and Ustilagineae
Saccardo - Sylloge Fungorum.
Just - Jahres Berichte.
Magnus - Papers on Ustilagineae.

Various other Journals, Magazines, Reports, and loose papers.

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Explanation of Plates.

Plate I. × 1000

Fig. 1-5, U. aristidae, 1. from edge of culture, mod. Colm Sol. 2-5, in water.

Fig. 6-8, U. cesatii on Andropogon scoparius in Mod. Colm Sol.

Fig. 9, Portion of old branch of U. filamentea from Bouteloua oligostachya in Mod. Colm Sol.

Fig. 10-13, U. austro americana in water.

Fig. 14, Spores in a mass of U. cesatii on Panicum capillare germinating. The ends a and b curve downward toward the surface of the culture drop (water).

Fig. 16, Same culture, peculiar conidia.

Fig 15 Same showing knee joints beginning to form between adjoining cells.

Fig. 17. Old promycelium with conidia, and germ tubes proceeding from knee joints at a and b the former passing under a spore mass at c.

Plate II.

Fig. 1-5, U. sorghi after 24 hours in water × 1200

Fig. 6-8, U maydis germination after 22 hours

in water, from fresh material collected in August 10 days before germination, x 1200.

Fig. 9, A portion of colony of budding conidia (U. Maydis Zeae) in Mod Cohn Sol. x 1200.

Fig. 10, Same species, old material after 24 hours in water, x 1200.

Fig. 11, 12, Dry plate cultures of same in moist chamber, x 370.

Fig. 13, Air conidia from exhausted culture in manure solution, x 2000.

Fig. 14-18, U. Reiliana after 3 days in water. x 1200.

Plate III.

Fig. 1, 2, U. Cesatii on Cenchrus tribuloides, spores, x 2000

Fig. 3, Spores of U. Cesatii (?) on Andropogon scoparius, x 2000.

Fig. 4, 5, Spores of U. Rabenhorstiana on Panicum sanguinale, x 2000.

Fig. 6, 7, Spores of U. Cesatii (?) on Panicum proliferum, x 2000.

Fig. 8-10, U. Cesatii (?) on Panicum proliferum, germination in water, x 1000.

Fig. 11-13, Germination of U. Cesatii on Cenchrus Tribuloides in mod. Cohn Sol.

after 3 days, × 1000.

Fig. 14-17, Germination of U. Andropogonis after 3 days in Mod. Cohn Sol. × 1000.

Plate IV.

Fig. 1, Spores of U. filamenta on Boutelova racemosa, × 1000.

Fig. 2, Spores of U. minor, × 1000.

Fig. 3,4, Germination of U. Cesatii (?) on Panicum proliferum, after several days in Mod. Cohn Sol., production of germ tubes from the promycelium, × 1000.

Fig. 5,6, Germination of Sorosporium cuneatum in water, × 1000.

Fig. 7-9, U. Rabinhorstiana after 3 days in Mod. Cohn Sol. Fig. 8, much swollen promycelia from both ends of the spore, × 1000.

Plate V.

Fig. 1. U. filamenta after 4 days in water × about 800.

Fig. 2. Typical germination of U. filamenta in Mod. Cohn Sol., after 48 hrs. × 1200.

Fig. 3. Air conidia (U. minor) after 8 days in Mod. Cohn Sol., almost dry at time of drawing. Spore and ends of long filaments not shown, × 1200.

Fig. 4, 5, U. filamenta beginning to germinate in water, after 18 hours, x about 1000.

Fig. 6, Germination of U. filamenta in Mod. Colm Sol., after 4 & 6 hours. Not a very vigorous specimen, x 120.

Plate VI. natural size.

Fig. 1, U. filamenta in inflorescence of Boutelona racemosa.

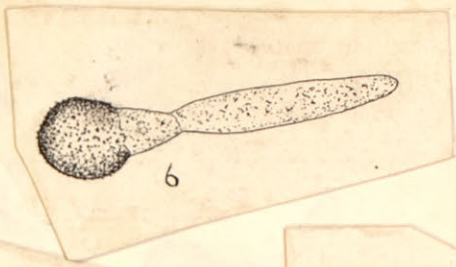
Fig. 2, 3, Usual appearance of U. filamenta on B. racemosa.

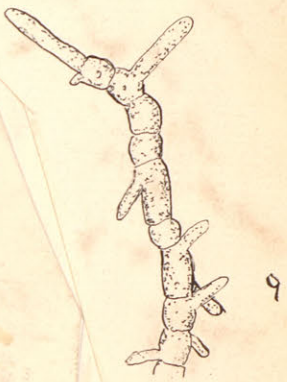
Fig. 4, Same on B. oligostachya.

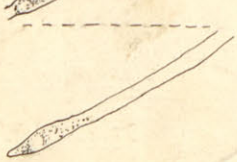
Fig. 5, Small portion of a plant of Boutelona hirsuta with U. minor.

Plate I.

1113







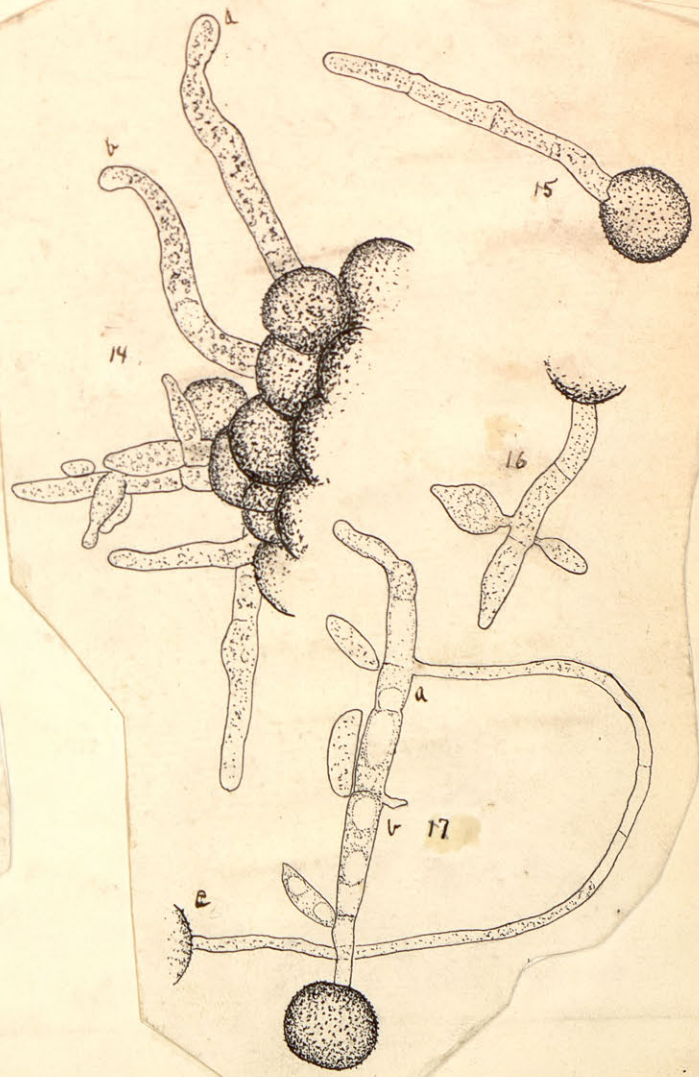


Plate II.

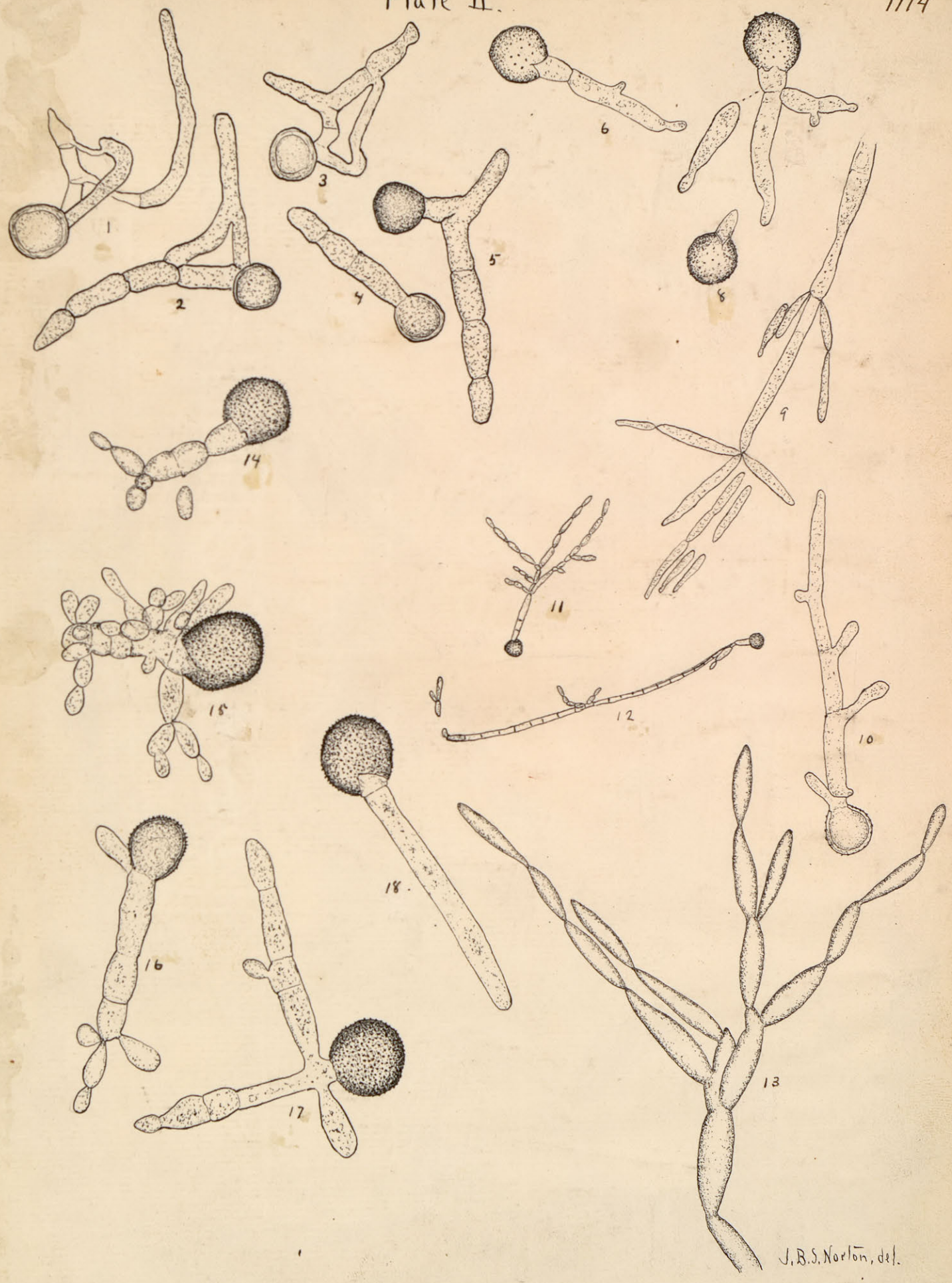
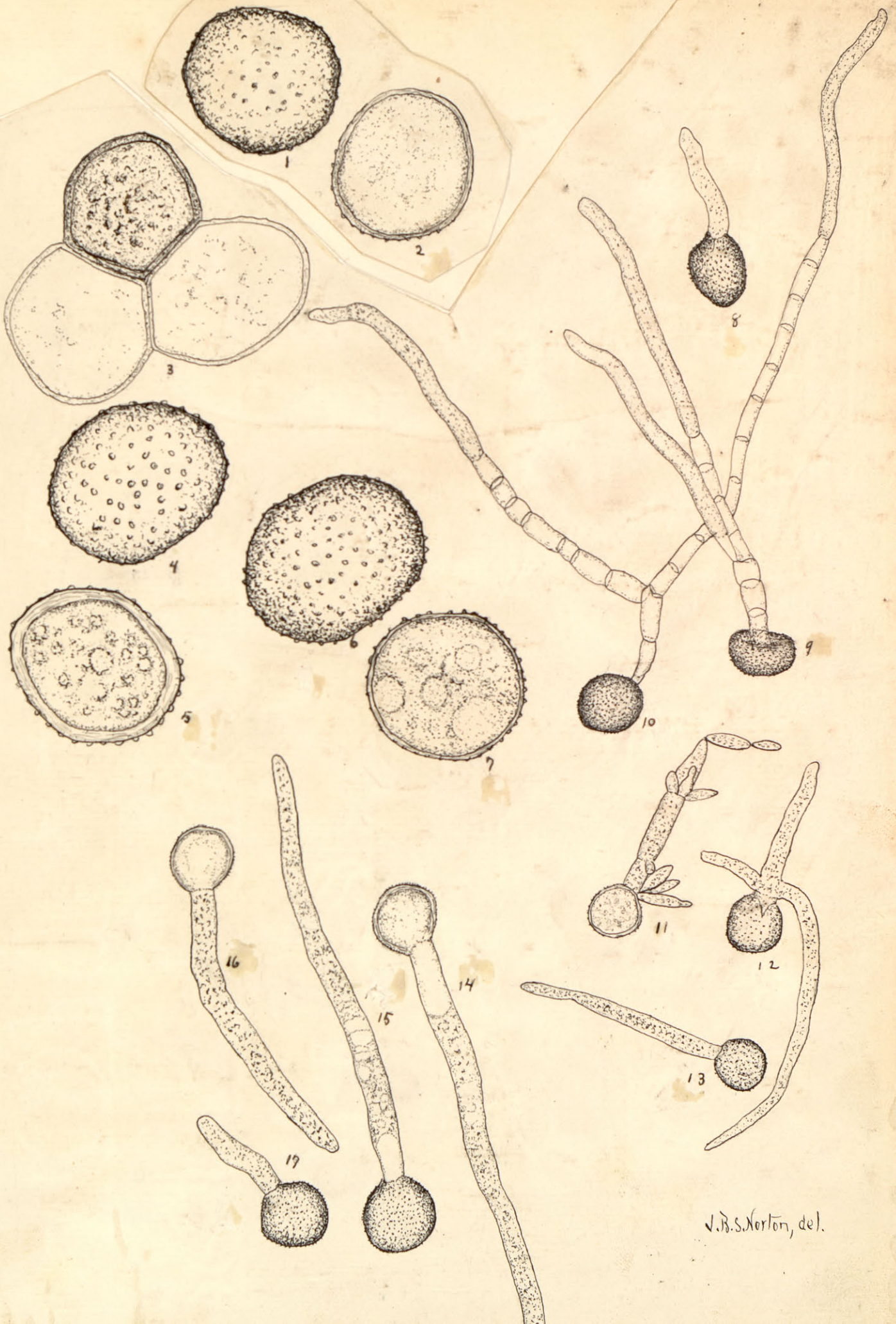


Plate III



J.B.S. Norton, del.

Plate IV.

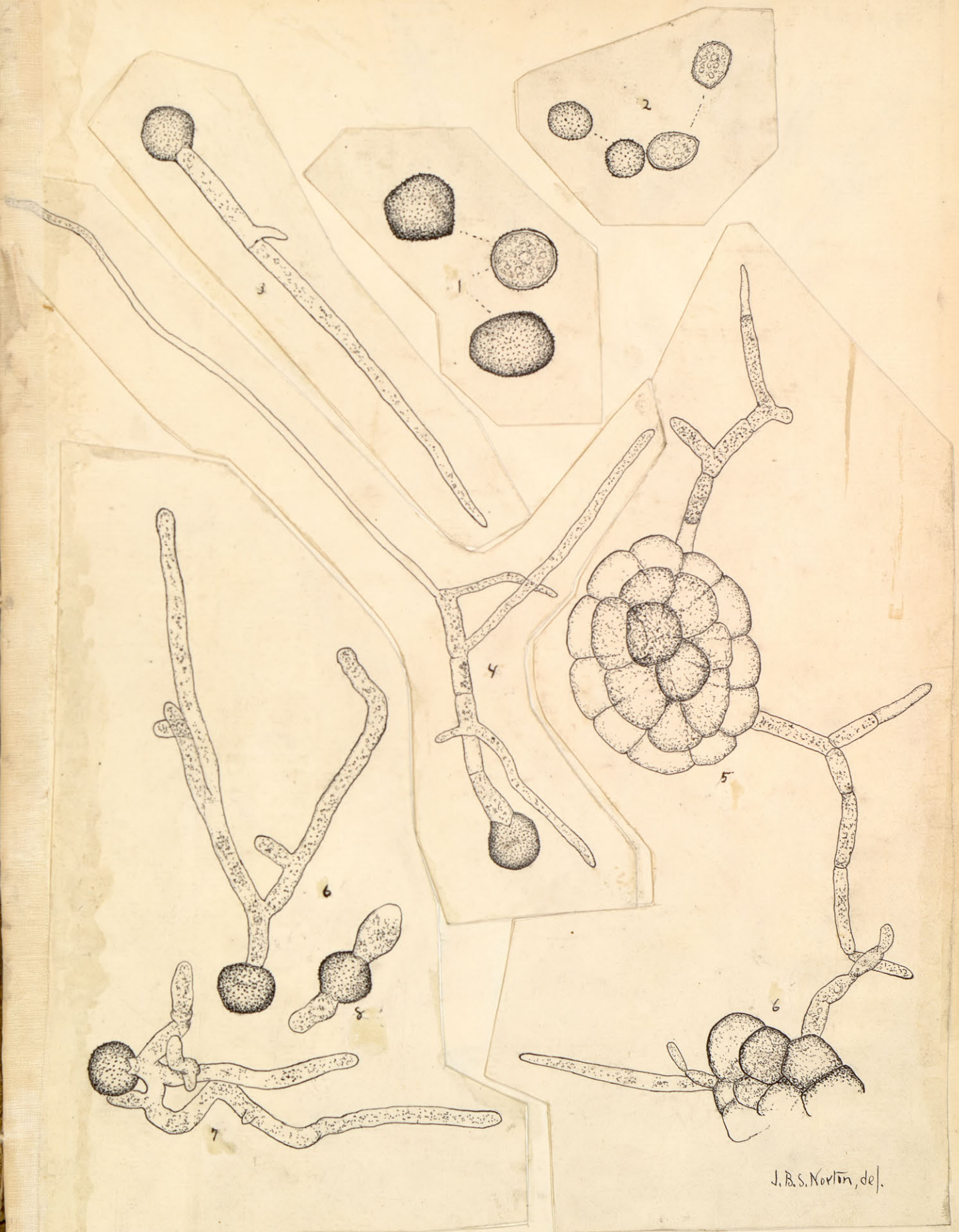


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Plate V.

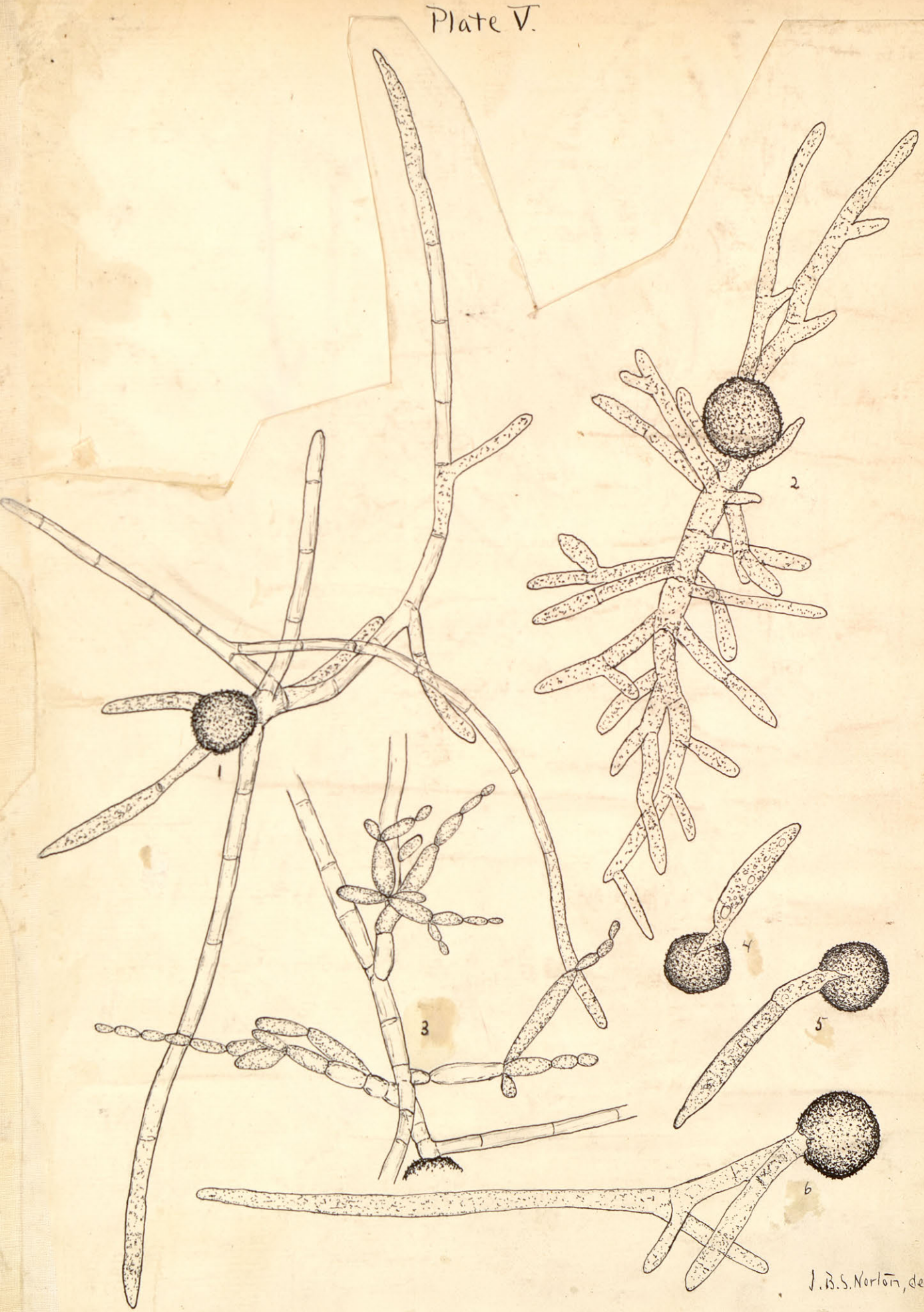
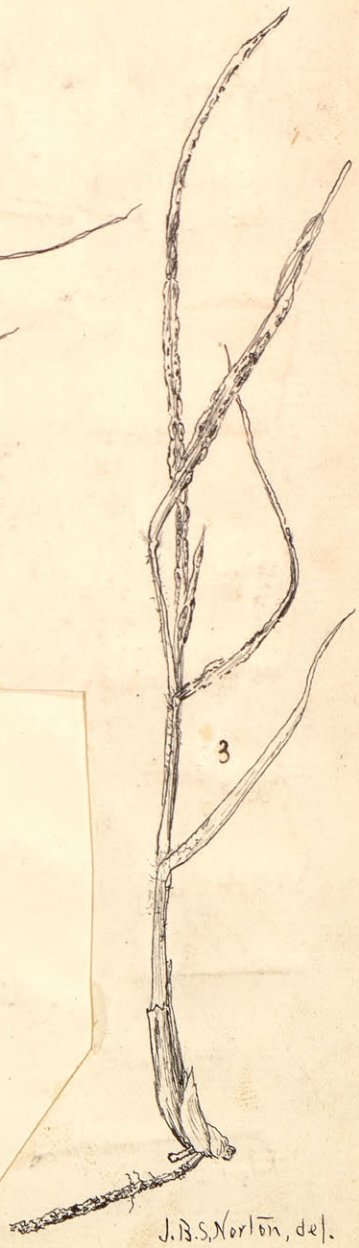


Plate VI.



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