PROCEEDINGS

OF THE

Iowa Academy of Science

FOR 1916

VOLUME XXIII

Thirtieth Annual Session, Held in Des Moines,
April 28 and 29, 1916

Published by
THE STATE OF IOWA
DES MOINES

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. . . . Morse Bluff, Neb.
Lazell, Fred J. . . . . . Cedar Rapids
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McNally, P. T. . . . . Iowa City
Merrill, D. E.. State College,
. . . . New Mexico
Moon, Helen . . . . Iowa City
Morbeck, Geo. C. . . . . Ames
Muilenburg, G. A. . . . . . Rolla, Mo.
Mull, Lewis B. . . . . Ottumwa
Nollen, Sarah M. . . . . Des Moines
Oleson, O. M. . . . . Ft. Dodge
Oncley, L. . . . . Fayette
Overholt, Sigel . . . . . Millersburg
Overn, O. B. . . . . Decorah
Paige, F. W. . . . . Ft. Dodge
Palmer, E. L. . . . . Cedar Falls
Plagge, H. J. . . . . Ames
Pomeroy, J. C. . . . . Ames
Quigley, T. H. . . . . . . Fargo, N. D.
Read, O. B. . . . . Cedar Falls

Reed, C. F. ....Lamoni
Reilly, Jno. F. ....Iowa City
Ressler, I. L. ....Ames
Reynolds, O. E. ....Iowa Falls
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Robinson, C. L. ....Iowa City
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Sargent, Louise ....Grinnell
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Schultz, Orville ....Postville
Shimek, Ella....Hamilton, Mont.
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Smith, Orrin H. ......Mt. Vernon
Somes, M. P. ....St. Paul, Minn.
Spencer, Clementina S. .... Cedar Rapids
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Stiles, Harold ....Ames
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Tenney, Glenn I. ....Des Moines
Thone, Frank E. A. .La Jolla, Cal.
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Werner, Herbert L. ....Ames
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Wifvat, Samuel ......Des Moines
Williams, A. J. ...Norman, Okla.
Wolden, B. O. ....Wallingford
Yothers, J. F. ....Toledo

CORRESPONDING FELLOWS.

Andrews, L. W. ....6643 Stewart Ave., Chicago, Ill.
Arthur, J. C. ....Purdue University, Lafayette, Ind.
Bain, H. F. ....London, England
Ball, C. R. ....Department of Agriculture, Washington, D. C.
Ball, E. D. ....State Entomologist, Madison, Wis.
Barbour, E. H. ....State University, Lincoln, Neb.
Bartsch, Paul ....Smithsonian Institution, Washington, D. C.
Bruner, H. L. ....Irvington, Ind.
Carver, G. W. ....Tuskegee, Ala.
Cook, A. N. ....University of South Dakota, Vermillion, S. Dak.
Drew, Gilman C. ....Orono, Maine
Eckles, C. W. ....University of Missouri, Columbia, Mo.
Fink, Bruce ....Oxford, Ohio
Franlin, W. S. ....Lehigh University, South Bethlehem, Pa.
Frye, T. C. ....State University, Seattle, Wash.
Gillette, C. P. ....Agricultural College, Fort Collins, Colo.
Gossard, H. A. ....Wooster, Ohio
Halsted, B. D. ....New Brunswick, N. J.
Hansen, N. E. ....Agricultural College, Brookings, S. D.
Haworth, Erasmus ....State University, Lawrence, Kan.
Hitchcock, A. S. ......Department of Agriculture, Washington, D. C.
Hume, N. H. ....Glen St. Mary, Fla.
Leonard, A. G. ....Grand Forks, N. Dak.
Leverett, Frank ....1724 University Ave., Ann Arbor, Mich.
Miller, B. L. ....Lehigh University, South Bethlehem, Pa.
Newell, Wilmon ....State Plant Board, Gainesville, Fla.
Osborn, Herbert ....State University, Columbus, Ohio
Price, H. C. ....Evergreen Farm, Newark, Ohio
Reed, Chas. C. ....Weather Bureau, New York City
Savage, T. E. ....Urbana, Ill.
Sirrine, Emma ....Dysart, Iowa
Sirrine, F. A. ....79 Sound Ave., Riverhead, New York
Todd, J. E. ....Lawrence Kan.
Trelease, William ....University of Illinois, Urbana, Ill.
Udden, J. A. ....University of Texas, Austin, Texas

Titles of Papers Received

The number following a title indicates the page of the Proceedings on which it may be found.

PAGE

Proceedings of the Thirtieth Annual Session, Held in Des Moines, April 28 and 29, 1916.

The Academy held its meetings in Memorial Hall, Drake University, corner University Avenue and 26th Street, Des Moines. The first session convened at 1:30 p. m., Friday, April 28th, with President Kelly in the chair. Following the general program the Academy divided into sections for the reading of papers.

Doctor Louis Kahlenberg, of the University of Wisconsin, gave the annual address, at 8:00 p. m., Friday, in the University Auditorium. His subject was "Some Results from the Experimental Study of Osmosis."

The Iowa Section and the Ames Section of the American Chemical Society held their sessions at 9:00 a. m., Saturday.

Members of the Mathematical Association of America met at 4:30 p. m., Friday, to organize an Iowa Section.

REPORT OF THE SECRETARY.

Fellows and Associates of the Iowa Academy of Science:

A study of the lists of the Academy membership during recent years shows that while there has been no marked increase in numbers the Academy has held its own, and that in spite of the numerous removals which occur every year. The Treasurer and the Secretary have carried on a follow-up campaign among those who have been tardy in keeping up their membership. A number of members have sent in during the year names proposed for membership. This is a welcome sign of activity and is a practice which should be followed still more energetically. It is not enough to maintain our membership at the same level. We should endeavor to raise it each year by continual work among those who are interested in scientific studies.

The recent volume of the Proceedings is the largest yet issued, and certainly has not been excelled in the quality of its contents. The action of the last Legislature in removing the page restriction has made this increase possible without casting an added burden on the treasury of the Academy. The pages are set one-half inch narrower than in previous volumes, a condition which leaves wider margins and improves the appearance of the book. I believe that this improvement more than offsets the few additional pages made necessary. I believe that you will agree with me that in physical qualities as well as in intellectual content our Proceedings are among the best of similar publications.

May I not urge upon you, in the spirit of greatest friendliness, the desirability, even the necessity of not only maintaining the high quality of the papers which are presented before the Academy, but of constantly raising our standards. For our personal satisfaction we must needs submit our work to the most rigid tests of accuracy of fact and purity of statement. For the honor of science and the reputation of our association we wish our work to broaden knowledge and advance truth upon its main lines of forward movement and as well upon those secondary lines of detail which are needed to complete the warp and woof of intellectual achievement. It should not be forgotten that all so-called "applied science" is simply "pure science" fitted to human need and made to minister to human betterment. There can be no higher aim in research than that of helping humanity rise to higher planes of physical well being, of mental attainment and of moral power. To ask you to continue to share in this effort is my privilege.

Two amendments to the Constitution have been submitted to the voting fellows of the Academy by the Executive Committee. These amendments suggest changes which the experience of the Academy has shown to be desirable and the Committee asks for your favorable consideration of these measures.

Very respectfully,

JAMES H. LEES,
Secretary.

REPORT OF THE TREASURER, 1915-1916.

RECEIPTS.

Cash on hand, May 1, 1915	$ 7.65
Dues from members	181.00
Initiation fees, fellows	12.00
Initiation fees, associates	34.00
Transfer fees, associates to fellows	8.00
From sale of proceedings	3.24
Total	$ 245.89

DISBURSEMENTS.

Honorarium and expenses of speaker, 29th meeting	$ 44.99
Supplies for the secretary	6.23
American Lithographing Co., 400 programs and 1,000 membership proposal blanks	14.30
Honorarium to secretary	25.00
To Miss Newman, wrapping and tying volume xxi	10.00
State binder, binding 200 copies Vol. xxi, and separates.	62.00
State binder, binding and separates Vol. xxii, on account	15.00
State printer, for excess pages Vol. xxi	50.00
Refund to bank on account of dishonored check	1.00
Supplies and postage for treasurer	11.75
Total	$ 240.27
Balance on hand	5.62

A. O. THOMAS,
Treasurer.

The Secretary submitted the following names for election in behalf of the membership committee:

The persons named were declared elected.

Transferred from Associate to Fellow—Forrester C. Stanley, Oskaloosa.

Elected as Fellows—I. E. Melhus, Ames; James H. Hance, Iowa City.

Elected as Associates—C. Herbert Belanski, Nora Springs; George E. Corson, Ames; James M. Davis, Dallas Center; Elmer Dershem, Iowa City, S. U. I.; L. W. Durrell, Ames, I. S. C.; Rev.

Ray Eckerson, Humeston; Miss Sophia J. Edmondson, 921 31st, Des Moines; Wm. G. Gaessler, Ames, I. S. C.; Dr. Daniel G. Glomset, Des Moines; C. Bert Gose, Indianola; C. A. Goss, Drake University, Des Moines; Earl G. Grissel, Iowa City (home Cedar Rapids); John L. Horsfall, Iowa City, S. U. I.; U. B. Hughes, Iowa City, S. U. I.; H. E. Jaques, Mt. Pleasant; A. R. Lamb, Ames, I. S. C.; Fred Metcalf, Dallas Center, High School (home Webster City); J. C. Pomeroy, Ames, Station A, I. S. C.; I. L. Ressler, Ames, I. S. C.; Walter E. Rogers, Iowa City, S. U. I.; Adolph Shane, 3300 4th St., Des Moines; Miss Clemantina Spencer, Iowa City, S. U. I.; L. M. Starin, Ames, I. S. C.; Herbert R. Werner, Ames, I. S. C.

LIST OF MEMBERS AND VISITORS IN ATTENDANCE.

John L. Tilton, Indianola; C. L. Coffin, Oskaloosa; F. C. Stanley, Oskaloosa; G. W. Stewart, Iowa City; Harry M. Kelly, Mount Vernon; L. S. Ross, Drake University, Des Moines; C. N. Kinney, Drake University, Des Moines; James H. Hance, State University, Iowa City; Urban B. Hughes, State University, Iowa City; Frank F. Almy, Grinnell College, Grinnell; Guy West Wilson, S. U. I., Iowa City; L. Begeman, Cedar Falls; M. F. Arey, Cedar Falls; John F. Reilly, Iowa City; E. A. Jenner, Indianola; C. Bert Gose, Indianola; Charles Carter, Fairfield; Geo. F. Kay, Iowa City; P. A. Bond, Cedar Falls; Orin H. Smith, Mt. Vernon; B. H. Bailey, Cedar Rapids; Arthur G. Smith, Iowa City; Samuel J. A. Wifvat, Des Moines; E. J. Cable, Cedar Falls; A. L. Bakke, Ames; James H. Lees, Des Moines; D. W. Morehouse, Drake University, Des Moines; F. O. Norton, Drake University, Des Moines; Dayton Stoner, Iowa City; H. A. Scullen, Ames; J. E. Guthrie, Ames; H. L. Dunlap, Iowa City; J. N. Pearce, Iowa City; A. W. Hixson, Iowa City; H. R. Werner, Ames; R. L. Webster, Ames; L. H. Pammel, Ames; L. B. Spinney, Ames; O. B. Read, Cedar Falls; S. F. Hersey, Cedar Falls; J. C. Pomeroy, Ames; J. A. Baker, Indianola; J. E. Fulcher, Des Moines College, Des Moines; L. Kahlenberg, Madison, Wis.; H. E. Jaques, Mt. Pleasant; Geo. E. Thompson, Ames, Iowa; George V. Emery, Ames; H. G. Anderson, Ames; L. E. Dodd, Iowa City, S. U. I.; Elmer Dershem, S. U. I., Iowa City; L. P. Sieg, S. U. I., Iowa City; W. B. Coover, Ames; S. W. Beyer, Ames; C. R. Keyes, Des Moines; C. C. Nutting, Iowa City; F. C. Brown, Iowa City; H. L. Dodge, Iowa

City; J. M. Davis, Dallas Center; F. G. Gates, Grinnell; Nicholas Knight, Mt. Vernon; R. C. Conklin, Des Moines; A. R. Lamb, Ames; G. O. Oberhelman, Grinnell; S. B. Kuzirian, Ames; W. G. Gaessler, Ames; Mr. and Mrs. L. A. Kenoyer, Ames; Elma Hanson, Des Moines; W. S. Hendrixson, Grinnell; W. J. Karslake, Iowa City; G. W. Roark, Jr., Ames; E. W. Rockwood, Iowa City; A. W. Dox, Ames; Sophia J. Edmondson, Des Moines.

At the business session on Saturday morning the following amendments to the Constitution were considered and adopted unanimously:

Section 3 was amended by making it read as follows: The membership of the Academy shall consist of *life fellows, fellows, associates, corresponding fellows* and *honorary fellows.* The *fellows* and *associates* must be elected from residents of the state of Iowa, the fellows being those that are actually engaged in scientific work. A *fellow* moving to another state becomes thereby a *corresponding fellow. Honorary fellows* shall be elected from the productive scholars in science residing outside the state of Iowa. All elections to membership shall be made at the annual meeting. The assent of three-fourths of the fellows present is required for the election of *fellows* and *associates.* An *honorary fellow* must be nominated by ten *fellows* of the Academy. This nomination, together with a record of the achievements in science of the nominee, must be given the Secretary and by him sent to each *fellow* previous to the annual meeting at which the election occurs. A unanimous vote of the *fellows* present is necessary for the election of an *honorary fellow.*

Section 4 and its adopted amendments were amended by making Section 4 read as follows: An entrance fee of $3.00 shall be required of each fellow and an entrance fee of $1.00 from each associate, and an annual fee of $1.00, due at each annual meeting after his election, shall be required of each *fellow, associate* and *corresponding fellow.* A person may become a *life fellow* on the payment of $15.00 after his election as a *fellow,* the transfer to be made by the Treasurer. The said life membership fee shall be invested and only the interest of the same shall be used for current expenses of the Academy. *Fellows, associates* and *corresponding fellows* in arrears for two years and failing to respond to notification from the Treasurer shall be dropped from the Academy roll.

G. E. Patrick

IN MEMORIAM.

G. E. PATRICK.

L. H. PAMMEL.

Professor G. E. Patrick was born in Hopedale, Massachusetts, October 22d, 1851, and died in Washington, D. C., on the 22d of March, 1916. At the time of his death he was in charge of the dairy laboratory of the Bureau of Chemistry of the U. S. Department of Agriculture. He graduated from Cornell University, receiving the degree of B. S. in 1873 and M. S. in 1874. He was instructor in Chemistry, Cornell University, 1873; assistant professor and professor of Chemistry, University of Kansas, 1874-1883; Chemist, Iowa Agricultural Experiment Station, 1889-1895, and professor of Agricultural Chemistry, Iowa State College, 1890-1895; since 1896 he was Assistant Chemist, U. S. Department of Agriculture; since 1901, chief of dairy laboratory of the same bureau. He was also, I believe, a member of the Delta Upsilon fraternity. He married Hattie E. Lewis of Lawrence, Kansas, in 1879, and she died in 1909.

Professor Patrick resigned from the Ames position because of some disagreement with the Board of Trustees. Soon afterwards he accepted a position with the Bureau of Chemistry of the U. S. Department of Agriculture in Washington, where he did splendid work. The disagreement at Ames he thought at the time was due to personal antagonism of Secretary James Wilson. However, when Professor James Wilson was made Secretary of Agriculture he found Professor Patrick in the Bureau of Chemistry where he was befriended in many ways by his supposed enemy. Professor Patrick told me many times in later years of his high regard for the Ex-Secretary and his family.

Professor Patrick published many chemical papers dealing with Dairy Chemistry. He was certainly active as shown by the number of papers either published by himself or associated with others, as the following numbers of the bulletins of the Iowa Agricultural Experiment Station show: Bulletin Iowa Agricultural Experiment Station 1: 11-15; 3: 82-91; 4: 99-103; 5: 143-160; 9: 355; 9: 356-369; 10: 448-480; 11: 481-489; 12: 519-529; 12: 530-534; 13: 5-30; 14: 123-151; 14: 152-165; 15: 199-233; 15:

274-283; 16: 354-355; 17: 389-392; 17: 393-418; 18: 478-487; 20: 690-705; 21: 788-791; 23: 925-939; 24: 969-984. He also contributed a few articles to the Proceedings of the Iowa Academy of Science: *14*: 73-75; *2*: 58-66. During the early days of the Iowa Geological Survey he was the chemist. The coal analyses were published in Iowa Geological Survey *3:* 504-599. Other analytic work done by him is reported in volumes *4* and *5*.

Professor Patrick was original and forceful and most industrious. Personally he was a most congenial companion. He was loyal to his friends, but most outspoken to those who differed from him. When he had his mind made up on a certain subject it was difficult to convince him of his errors. He would argue the point for hours. In recent years his views on many subjects were greatly modified. In my conversation with him in recent years I found him to be most considerate for the opinion of others. He has left a host of warm, personal friends.

HARRIETTE KELLOGG.

L. H. PAMMEL.

The subject of this sketch was born in Grinnell, Iowa, August 23, 1860, and died in Marshalltown, Iowa, from pneumonia following an operation, on January 6, 1916. She received her early training in the Grinnell schools, and after completing a classical course in Grinnell College in 1880, she pursued graduate work in her alma mater and at the University of Chicago, receiving from her alma mater the A. M. degree. After her graduation from Grinnell College she taught in the public schools of various cities in Iowa and in Glenco, Minnesota, where she taught Latin and literature in Stevens Seminary. She came to Iowa State College as curator of the herbarium and in charge of the botanical library in 1903. I have known of few persons who discharged their duties more faithfully than Miss Kellogg. So far as I can learn she did not publish much before coming to Ames. Her previous training was a preparation for the work later accomplished by her. I find that she contributed to the proceedings of the Iowa Academy in the following volumes. *19:* 113-128; *22:* 60-75. She assisted in the preparation of the Lacey Memorial volume published by the Iowa Park and Forestry Association. She also prepared the bibliography in the writer's Manual of Poisonous Plants and the Weed Flora of Iowa and Weeds of

Harriette Kellogg

the Farm and Garden. At the time of her death she was engaged on the history and bibliography of the Botanical Department of Iowa State College. I should like to call attention, especially, to the indices prepared by her of the Manual of Poisonous Plants, the Weed Flora of Iowa and the Lacey Memorial Volume, which show rare ability in the grasping of a subject. The preparation of these involved an enormous amount of labor and fine constructive ability.

It was a pleasure to have been associated with Miss Kellogg for thirteen years at Ames and in all of these years she was always of the same cheery disposition. She never shirked in her duty. Her work was always well done. Miss Kellogg had a winning personality and always had something good to say about others. She left a host of sorrowing friends in the community where she spent the closing years of her life.

Miss Kellogg will be missed not only in the meetings of the Iowa Academy but most of all by those who were privileged to be intimately acquainted with her in her daily work.

Papers Presented at the Thirtieth Meeting of the Academy

PURE SODIUM CHLORIDE.

NICHOLAS KNIGHT.

It is often convenient and necessary to have on hand a supply of pure sodium chloride for the preparation of standard solutions. It is quite easy to obtain the substance with a "C. P." label, but it does not always follow that the article is as pure as the label may indicate.

It seems to be a difficult matter to obtain common salt that is entirely free from potassium chloride. We have prepared sodium chloride by different methods. We have tested these and also the various samples we had on hand in the laboratory stock room, and have usually found a small quantity of potassium chloride present.

1. We prepared a saturated solution of ordinary common salt, into which we passed hydrogen chloride, made by heating pure concentrated hydrochloric acid. We filtered off the salt crystals using a pump and after drying we obtained 0.42 per cent of potassium chloride.

2. We dissolved 100 grams of ordinary common salt in 300cc water and filtered into an evaporating dish. This was heated to boiling, and milk of lime added in small excess. The precipitate was filtered off, and the excess of calcium and barium precipitated with sodium carbonate. It was again filtered and the excess of sodium carbonate was changed to sodium chloride with pure dilute hydrochloric acid. After drying we found in the specimen 0.32 per cent of potassium chloride.

3. We made a solution of caustic soda by dissolving metallic sodium in distilled water, and we neutralized this with pure hydrochloric acid. The analysis of the dried salt showed 0.27 per cent of potassium chloride. The sodium must have contained a small quantity of metallic potassium.

4. The foregoing experiment was repeated using the purest caustic soda in the laboratory that had not been purified by alcohol. The resulting sodium chloride showed 0.48 per cent potassium chloride.

We next examined three specimens of salt, each of which was supposed to be chemically pure. The following results in potassium chloride were obtained:

1. 0.57 per cent potassium chloride.
2. 0.45 per cent potassium chloride.
3. 0.49 per cent potassium chloride.

In each of the seven samples of salt examined, the presence of the potassium could be distinctly seen with the flame test, using a piece of blue glass.

The method we employed in separating the sodium and potassium chlorides is the following: We dissolved about a half gram of the salt in a little water and added perhaps twenty drops of a ten per cent solution of platinic chloride. Then we added a few drops of water and moved the mass back and forth till it flowed freely. There is some difficulty of manipulation here, as too little water would not dissolve all the $Na_2 Pt Cl_6$, and too much would dissolve some $K_2 Pt Cl_6$. We filtered and washed first, five or six times with one volume of water and a half volume of alcohol, then about six times with a mixture of alcohol and ether. After drying the precipitate, it was placed over a weighed platinum crucible and washed into the crucible with boiling water. It was evaporated to dryness on the water and dried in a thermostat at 105 degrees.

Our thanks are due Clifford Lahman and Lester Rusk for assistance in the analytical work.

BARIUM IN TOBACCO AND OTHER PLANTS.

NICHOLAS KNIGHT.

Scheele in 1788 first observed that barium is found in plants, as he obtained it from beech trees. Forchammer in 1855, detected its presence in the ashes of beech, oak and birch trees. In the same year, Eckhard and Boedeker confirmed its existence in beech and found it also in the sandstone near Goettingen.

In 1874, Knap of Leipzig, while investigating the mud carried down by the Nile river found that barium was present. The following year, Dwarzak confirmed the presence of barium in the Nile mud, and found it in the leaves, ear and stalk of wheat grown in the Nile valley.

A number of investigations have been made in the United States by the Bureau of Plant Industry and the Bureau of Soils, for the detection of barium. The work in this country has been done to ascertain, if possible, if the poisonous properties of the Loco weed which causes the Loco disease in cattle, is due to the presence of barium in the plant.

J. S. McHargue, Journal of the American Chemical Society, June, 1913, describes his work that shows the presence of barium in tobacco and in various others plants.

Many are doubtless more or less familiar with the wide distribution of barium in soils. The old igneous rocks have disintegrated into simpler compounds which finally have become available as food for the growing plant. It is still a question whether barium should be considered a plant food at all, although it is found more or less in the vegetable kingdom, but not in all the species that have been investigated.

We have examined the leaves and stems of a number of specimens of tobacco, grown in Sumatra, Cuba, and in various parts of the United States. We desire to express our thanks to Mr. J. M. Goldstein, of Oneida, New York, for kindly supplying most of the specimens.

Our method was essentially that outlined by McHargue in the paper referred to. We selected twenty-five grams of the leaves which were just sufficiently moist to prevent crumbling. These were cut into small bits and placed under a hood as the odors are very disagreeable. The combustion is made with one Tirrell burner in about two hours. Too great heat is not desirable as it fuses the ash and renders it more difficult to handle. The ash is weighed and while in the platinum dish, it is dampened with distilled water, 15cc. of hydrochloric acid is added, and it is heated twenty minutes on the water bath to complete the reaction. There are two conditions in which the barium seems to exist in the ash—a part soluble in hydrochloric acid, and an insoluble portion which is barium sulphate. The precipitate containing the barium sulphate with the ashes of the filter paper is placed in a platinum crucible to which are added a few drops of dilute sulphuric acid and 10cc. of hydrofluoric acid. It is digested slowly for several hours over a free flame. This decomposes the silicates, and the residue is evaporated to dryness. Next a sodium carbonate fusion is made with about *four* grams to decompose the barium sulphate.

The residue is changed to barium chloride with hydrochloric acid and added to the first hydrochloric acid filtrate. These are heated to boiling and the barium precipitated in the usual way with a few drops of sulphuric acid. We treated the stems in the same way.

As the ash is chiefly carbonates, we found difficulty in getting a constant weight, as the CO_2 would be driven off by the heat. The per cent of the ash represents the mean of two or more determinations.

Kind of Tobacco	Per cent of Ash	Per cent of $BaSO_4$ in the Plant
Havanna Tobacco from Cuba—		
Leaf	20.85	.0608
Stem	25.68	.0760
Broad leaf grown in Pennsylvania—		
Leaf	21.98	.0648
Stem	21.62	.0780
*Havana seed grown in Connecticut		
Leaf	20.11	.0600
Stem	19.38	.0720
Pennsylvania Tobacco grown in Pennsylvania—		
Leaf	21.48	.0980
Stem	24.28	.1280
Sumatra Tobacco—		
Leaf	20.81	.0308
Stem	24.73	.0408
Wisconsin Tobacco grown in Wisconsin—		
Leaf	21.62	.0192
Stem	24.49	.280
Tobacco from farm of Leon Bequillard, Mexico, N. Y.—		
Leaf		.0132
Stem		.0504

*Grown under canvas tents.

Kind of leaf	Per cent of $BaSO_4$
Dogwood leaf	.0224
Cottonwood leaf	.0052
Cherry leaf	.0392
Black locust	.0324
Mulberry leaf	.0696
Elm leaf	.0356
Linden leaf	.0152
Wild olive	.0048
Plum	.0372
Box elder	.0360
Hard maple	.0368
Walnut	.0752
Pear	.0196

The leaves were taken from trees on the Cornell College campus, or from the village of Mount Vernon. They were gathered in the autumn and so were mature leaves. An analysis of a sample of soil from the campus showed .1312 per cent of barium sulphate.

We desire to express our hearty thanks to Harold L. Maxwell and Lester W. Rusk for making the analyses of this paper.

SOME ROCK ANALYSES.

NICHOLAS KNIGHT.

I. A specimen from the Plains of Abraham.

The rock was picked up on the Plains of Abraham, above Quebec, but came from a quarry in the neighborhood. The analysis was made by Mr. O. E. LaRue, and shows the rock to be a sandstone with a considerable admixture of Calcium and Manganese Carbonates. The result is as follows:

	Per cent
SiO_2	54.54
Fe_2O_3	5.37
Al_2O_3	6.64
$CaCO_3$	15.12
$MnCO_3$	18.33
	100.00

The specific gravity is 2.69.

II. A specimen from the Alps.

The rock was obtained from the Alps near Lucerne, Switzerland, and is used there as a building and road material. The analysis by C. M. Peddycoart shows it is an impure limestone.

	Per cent
SiO_2	11.81
Fe_2O_3	4.21
Al_2O_3	1.15
$CaCO_3$	70.23
$MgCO_3$	8.17
H_2O	4.26
	99.83

III. Limestone from the Madeira Islands.

The Madeira Islands lie northwest of Africa and about three hundred and sixty miles from the coast. The group belongs to Portugal. The soil is very fertile, and the tropical and subtropical vegetation is very luxuriant. The specimen is a limestone, as the analysis by Henry F. Carlton shows.

	Per cent
SiO_2	1.17
Fe_2O_3	0.61
$CaCO_3$	94.11
$MgCO_3$	4.21
	100.10

This specimen represents the paving material used at Funchal, the chief city of the Islands. Automobiles are now invading the locality but the former rapid transit was the toboggan used in the streets for descending the hills and mountains, and the primitive ox cart. The paving from this rock wears to a smooth, hard metallic-like surface which facilitates the traffic.

IV. Igneous rock from Madeira.

This is a brownish appearing rock which easily disintegrates and crumbles to a fine powder. It seems to be the origin of the fertile soil of the islands. The analysis was made by Miss Nela Smart.

	Per cent
SiO_2	43.96
Fe_2O_3	15.02
Al_2O_3	12.44
$CaCO_3$	15.49
$MgCO_3$	9.05
TiO_2	2.02
Na_2O	0.68
K_2O	0.15
H_2O	1.05
	99.86

This group of islands is of volcanic origin.

Department of Chemistry,
Cornell College.

AN IMPROVED METHOD OF DETERMINING SOLUBILITY.

W. S. HENDRIXSON.

In the continuation of work on acid sodium and acid potassium phthalates as standards in acidimetry and alkalimetry[1], it seemed desirable to study among other properties, the solubility of these salts.

It seems to be generally recognized that none of the methods for determining solubility is wholly satisfactory. Among the major difficulties are these: The somewhat complicated machinery necessary to agitate the liquid in the thermostat, and the solvent, and the difficulty of securing a specimen of the clear solution for analysis, without change of temperature. Since this laboratory, like most others, is supplied with a practically un-

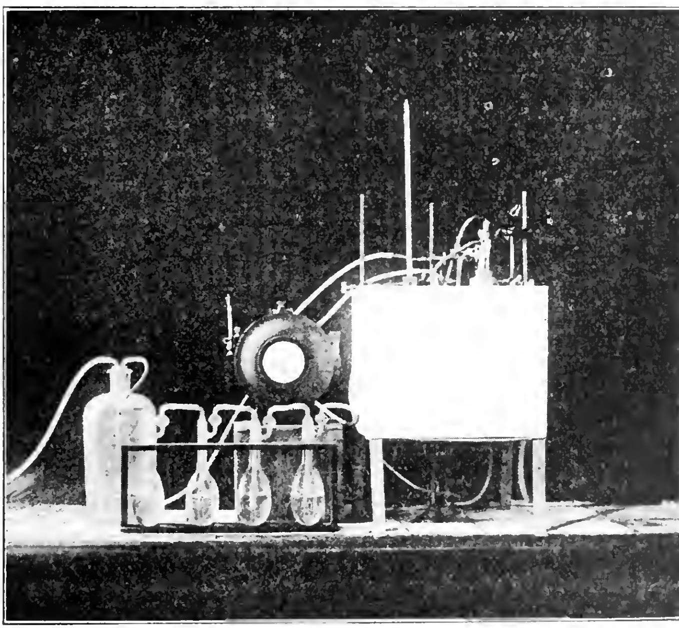

FIG. 1.

limited amount of compressed air, the attempt has been made to use it for the agitation of solvent and bath. To avoid the second difficulty a special form of pipet has been used, which could be wholly submerged during the time of agitation so as to be at the

[1]Proc. Iowa Acad. Sci., Vol. XXII, p. 217.

same temperature as the solution. The results have been so satisfactory that a statement describing the method apart from the main subject of investigation seems to be justified.

The arrangement of the whole apparatus is shown in figure 1. About ten gallons of water are contained in a tank of sheet iron covered with layers of asbestos, felt and canvas. The regulator is the ordinary form of Ostwald, designed for heating with gas. The vessel for the solution is a large test-tube and it contains a pipet holding about 20cc. as shown in figure 2, A. A large rubber stopper was cut through to one of the holes, the shank was inserted into the hole and the cut was closed with rubber cement. A second pipet for higher temperatures where the solu-

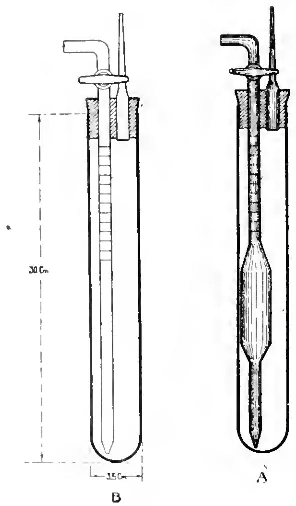

FIG. 2.

tion became more concentrated, is shown in figure 2, B. The meter shown in figure 1 is a test gas meter reading to .001 cubic foot.

At first the thought was to stir both the bath and the solvent with the same stream of air, but this introduced undesirable complications and two streams were used. Ordinary air from the reservoir was passed into the bath at the bottom and near the middle at the rate of about three cubic feet per hour, which was found ample as shown by two standard thermometers whose bulbs were placed in different parts of the bath for comparison.

The air for the solution was first passed into a large bottle having a layer of strong potash solution, then through four bottles of the same sort of solution of concentration 1 to 2. It then passed through the meter and through four gas washing bottles with water which were wholly immersed in the bath. The purpose of these last bottles was to saturate the air with water vapor at the temperature of the bath. The use of air for stirring in such cases is not new[2], but so far as could be ascertained there has been no attempt to compensate for the unavoidable loss of solvent by evaporation. The air then passed through the pipet and into the solution. The bottles, tube for the solution, the pipet and all connections, save only the tip of the capillary exit tube from the solution vessel, were wholly immersed.

Before undertaking actual determinations of solubility the degree of compensation for evaporation was tested by many experiments extending over periods from one to five hours, at temperatures from 25° to 65°, the rate of the air current being about 1.5 cubic foot per hour. This rate is sufficient for the agitation of the solution. The tube containing the water and pipet was weighed at the beginning and end of each experiment. In some experiments there was a small loss, in others a slight gain in weight, the difference never amounting to more than .035 gram per cubic foot of air. Since it was shown that the gain or loss was closely proportional to the volume of air, and, therefore, to the time, it is evident that it could not exert any appreciable influence on the results in such work. A few blank tests have been made at 80°. At this temperature there was an apparent loss of about 0.2 gram of solvent per cubic foot of air. This loss is probably due to secondary causes that it may not be possible to eliminate at such a high aqueous tension. Even if confirmed by later experiment it seems hardly probable that it could cause a degree of supersaturation that could materially affect the results. However, there are other considerations that make it seem probable that this method is best suited for moderate temperatures, and that at or near the boiling point of the solvent some one of the special methods for such temperatures may more conveniently be used.

In carrying out an actual determination the substance under investigation was dissolved in about 60cc. of water in sufficient

[2]Pawlewski, Berichte d Deutsch Chem. Gessel., p. 1040.

amount to give an abundant crystallization on cooling to the desired temperature of the experiment. The calibrated pipet was so inserted as to leave its tip above the surface of the solution. The whole was then placed in the bath and when solution and bath were near the same temperature the air was started through the pipet which was then lowered into the solution. At the end of a two-hour period the pipet was raised slightly, its stop-cock was turned and the hose conducting the air was removed. In a few moments the solution became perfectly clear, and the pipet was filled with it to the stop-cock by suction. The pipet was removed, washed, dried and weighed. The solution was run into the titration flask, and the pipet was washed into the same with warm water. The whole was then titrated. From the weights and known volume of the pipet, the concentration per gram and per cc. and also the density of the solution could be readily calculated.

No filtering device for the pipet was necessary, nor any drip cap, since the solution could not run out till the stop-cock was opened. With other substances which settle slowly or not at all it would be necessary to use a filtering device of gauze or other material as in other methods. In such case it would probably be better to pass the air into the solution through an extra tube and not through the pipet.

After pipetting out at the end of the first experiment the test-tube and remaining solution were left in the bath. After emptying the pipet and drying it, it was reinserted and a second experiment was carried out extending over an additional period of two hours, or four hours in all. The duplicate experiments give almost perfectly concordant results. These and other data on the acid phthalates are reserved for another communication.

Chemical Laboratory,
Grinnell College.

THE BEHAVIOR OF SOLUTIONS AT THE CRITICAL TEMPERATURES—A PRELIMINARY REPORT.

PERRY A. BOND.

The writer has felt that at or about the critical temperature of solutions, there might be found phenomena which would throw light on the mechanism of the formation of solution. The question of whether the solvent is chemically combined with the solute, whether in all or only in special cases, is the final object of the research.

Thus far the work, carried on in liquid sulphur dioxide, has given only hints of what may be expected, but enough has been accomplished to show that interesting results may appear.

In addition to the question of the solubility of a solid in the gaseous phase which is now being studied, it is expected that the electrical conductivity of the solutions as they approach the critical temperature will be investigated. The great problem in a practical way lies in the fact that the pressures under which all the experiments must be made lie close to 80 atmospheres, and in glass tubes which are essential for the work as outlined, the risk of explosion and consequent loss of calibrated instruments is very great.

A more extensive report will be made in next year's Proceedings.

DEPARTMENT OF CHEMISTRY,
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SOME AUXOAMYLASES.

(ABSTRACT.)

ELBERT W. ROCKWOOD.

The amylases, or starch splitting enzymes, are aided, or have their activity increased, by certain nitrogenous compounds particularly those which contain the NH_2 group. These amylolytic stimulating substances I have called auxoamylases. All amino compounds are not auxo substances, however. The experiments described here have been made to ascertain what compounds do activate the amylases and the conditions which affect their action.

Method.—Boiled starch solution was digested at 38° with dilute enzyme solutions under toluene, portions being removed at intervals for testing. The degree of hydrolysis was determined by heating the digested solution on a steam bath with an excess of Fehling's solution, filtering off the cuprous oxide formed, dissolving this washed precipitate in nitric acid, boiling off the nitrous acid, neutralizing the excess of acid, making acid with acetic acid and precipitating the copper as CuCl with KI. The iodine thus liberated was determined by titration with tenth-normal $Na_2S_2O_3$ solution. The quantity of reducing sugar formed by digestion of the starch is, consequently, proportional to the $Na_2S_2O_3$ used. Since the hydrogen ion has a marked effect on amylases, when the amino compounds had an acid reaction they were carefully neutralized before the digestion.

The following classification of the nitrogen compounds was found:

AUXOAMYLASES.

Glycine, $NH_2CH_2CO_2H$.
Tyrosine, $HOC_6H_4CH_2CH(NH_2)CO_2H$.
Hippuric acid, $C_6H_5CONHCH_2CO_2H$.
Anthranilic acid, $NH_2C_6H_4CO_2H$.
Asparagin, $NH_2COCH_2CH(NH_2)CO_2H$.

INACTIVE NH_2 COMPOUNDS.

Sulphanilic acid, $NH_2C_6H_4SO_3H$.
Acid amids like,
Urea, $(NH_2)_2CO$.
Acetamid, CH_3CONH_2.
Propionamid, $CH_3CH_2CONH_2$.

Table 1 gives some of the details of such a digestion showing that asparagin acts as an auxoamylase but acetamid does not.

TABLE NO. 1.

ACETAMID AND ASPARAGIN.

Each contained 5 cc. toluene and 180 cc. 1 per cent starch.

A. 10 cc. water and 10 cc. of 3 per cent saliva.

B. 0.5 grm. acetamid in 10 cc. water and 10 cc. saliva.

C. 0.5 grm. asparagin, (neutralized) in 10 cc. of water and 10 cc. of 3 per cent saliva.

Degree of digestion shown by cc. of $Na_2S_2O_3$ used:

Digested one hour.
A= 4.45 cc. $Na_2S_2O_3$
B= 4.18 cc. "
C= 5.90 cc. "

Digested two hours.
A= 8.6 cc. $Na_2S_2O_3$
B= 8.9 cc. "
C=10.1 cc. "

Digested four hours.
A=15.1 cc. $Na_2S_2O_3$
B=14.85 cc. "
C=18.35 cc. "

Digested six hours
A=17.9 cc. $Na_2S_2O_3$
B=17.0 cc. "
C=19.1 cc. "

Digested 24 hours.
A=25.0 cc. $Na_2S_2O_3$
B=24.5 cc. "
C=27.8 cc. "

In the succeeding tables the details are omitted but the figures, as before, represent the amounts of sugar formed from the starch.

TABLE NO. 2.

ACTION OF GLYCINE.

200 cc. of starch-saliva solution used.

Glycine used	0.5 hour	1.5 hours	4.0 hours	5.5 hours
None	3.95	9.70	16.1	18.75
0.1 grm..........	6.00	11.25	17.2	20.40
0.3 grm..........	9.00	12.80	18.7	21.20
0.5 grm..........	8.20	16.50	22.2	23.25

TABLE No. 3.

TYROSINE.

Tyrosine used	40 min.	1.75 hrs.	4 hrs.	6.25 hrs.	24 hrs.
None	1.25	5.35	9.65	11.15	18.55
0.05 grm.....	2.85	6.20	11.30	13.72	22.25
0.1 grm......	3.35	6.55	12.10	13.65	24.00

The volume of the digestion solution was 200 cc.

The amylase was ptyalin.

TABLE NO. 4.

HIPPURIC ACID (neutralized).

Digested hours	No hippuric acid	1.2 grm. hippuric acid in 200 cc. solution
1	4.5	9.3
2	9.2	14.8
4	14.05	18.35
24	18.8	20.2

TABLE NO. 5.

ANTHRANILIC ACID (neutralized).

200 cc. of starch-saliva solution used.

Anthranilic acid used	1 hour	3 hours	5 hours	25 hours
None	5.5	12.2	15.1	23.9
0.1 grm	7.1	14.3	17.1	25.8
0.3 grm	8.3	15.6	18.5	25.9
0.5 grm	8.8	16.4	18.7	25.1

TABLE NO. 6.

ACTION OF GLYCINE ON PANCREATIC AMYLASE.

1 cc. of pancreas solution.

Glycine	30 min.	1 hr. 40 min.	2 hr. 20 min.
None	14.6	23.9	24.8
0.5 grm	21.1	27.4	30.9

5 cc. of pancreas solution.

Glycine	30 min.	1 hr. 40 min.	2 hr. 20 min.
None		28.7	29.1
0.5 grm		32.2	35.9

TABLE NO. 7.

ACTION OF UREA ON PTYALIN.

200 cc. starch-saliva solution.

Digested hours	No urea	0.5 grm. urea
2	1.8	2.1
4	3.5	3.6
6	4.0	4.0
24	9.1	9.1

TABLE NO. 8.

SULPHANILIC ACID (neutralized).

Digested hours	No sulphanilic acid	1.3 grm. Na Sulphanilate in 200 cc. of solution
0.5	7.4	7.5
1.5	14.3	14.6
4.0	18.9	19.8
6.0	20.8	21.0

The work is being continued. Its importance is seen from the fact that amino acids are produced by digestive proteolysis and that they must act in the intestine as hormones to the amylolytic enzymes.

A COMPARISON OF BARBITURIC ACID, THIOBARBITURIC ACID AND MALONYLGUANIDINE AS QUANTITATIVE PRECIPITANTS FOR FURFURAL.

ARTHUR W. DOX AND G. P. PLAISANCE.

All of the methods for the quantitative determination of pentoses and pentosans in agricultural products are based upon the conversion of pentose into furfural by distillation with a mineral acid, preferably hydrochloric, and subsequent estimation of furfural in the distillate by means of a suitable reagent. Günther, Chalmot and Tollens[1] titrated the furfural with phenylhydrazine, using aniline acetate paper as an indicator. Stone[2] made use of the same reaction, but used Fehling's solution to determine the excess of phenylhydrazine. Later, Flint and Tollens[3] showed that this titration method was not accurate, on account of the levulinic acid resulting from the decomposition of hexoses, as well as the instability of the standard phenylhydrazine acetate reagent used. Jolles[4] titrated the furfural with potassium bisulphite and iodine. In the absence of other reducing substances, the furfural could be determined directly with Fehling's solution. Günther and Tollens[5] precipitated the furfural as hydrofurfuralimide by means of ammonia, while Chalmot and Tollens[6] used phenylhydrazine and weighed the resulting hydrazone. In both cases the condensation product was somewhat soluble.

Councilor[7] was the first to use phloroglucinol for the quantitative determination of furfural. This method was later studied and perfected by Tollens and his co-workers. The phloroglucinol method, although known to be faulty in several respects, is the one in general use today, having been adopted as provisional by the Association of Official Agricultural Chemists.[8] It is strictly empirical, since the nature of the reaction and the constitution of the condensation product have not been determined. Kröber[9] compiled a table in which the weight of furfuralphloroglucide obtained is interpreted in terms of furfural, xylose, arabinose or pentose. This table is purely empirical, being based on trial distillations and precipitations of the furfural or the particular pentose employed, and not upon the molecular weight of the condensation product. Furthermore, this method calls for solubility corrections. Kröber assumes that two molecules of water are split out in the reaction between furfural and phloroglucinal. Goodwin and Tollens[10] claim that only one molecule of water is liberated at ordinary temperature, but if the reaction is carried out at a temperature of 80° three molecules are liberated. A slight variation in the conditions may, therefore, affect the result considerably. Kröber noted the fact also that when the phloroglucide is allowed to stand in the air for a time, it takes up moisture which cannot be expelled by subsequent drying. From this brief survey of the literature, it is obvious that the phloroglucinol method in common use is not altogether satisfactory.

Other reagents also have been tried with varying success. Kerp and Unger[11] used semioxamizine as a precipitant for furfural, but obtained results that were too low. Conrad and Reinbach[12] found that furfural and barbituric acid condensed in the presence of dilute hydrochloric acid. Subsequently, Unger and Jäger[13] applied this reaction to the quantitative determination of furfural. They found that six to eight times as much barbituric acid as the theory required was needed to give the calculated value for furfural. The condensation product had the advantage of being only very slightly soluble in hydrochloric acid (1.22 mgm. per 100 cc.). They claim that barbituric acid does not precipitate the furfural derivatives of hexose origin and that these merely tend to color the solution yellow. The reaction is a very simple one, consisting in the condensation of one molecule of furfural and one molecule of barbituric acid, through the aldehyde group of the former and the methylene group of the latter, with the splitting out of one molecule of water. The product was found to contain 13.75 per cent nitrogen, which is in close agreement with the calculated value of 13.63 per cent. When prepared from the furfural distillate from natural sources, the product was found to contain 13.96 per cent nitrogen.

Fromherz[14] used barbituric acid as a precipitant for methylfurfural, and found the condensation product to be not appreciably soluble. Fallada, Stein and Ravinka[15] found that barbituric acid and phloroglucinol gave very nearly the same results when pure xylose and arabinose were distilled and precipitated. On the other hand, when sucrose was added to the pentose, the results were very much higher when phloroglucinol was used as a precipitant than when barbituric acid was employed, the latter giving normal values. This substantiates the statements of other workers who found that hydroxymethylfurfural was not precipitated by barbituric acid.

The barbituric acid method possesses, therefore, certain advantages over the phloroglucinol method, in that the reaction is more specific and a definite condensation product is formed. The precipitate, however, is sufficiently soluble to render a solubility correction necessary. Then again, a large excess of the reagent appears to be necessary, indicating that possibly an occlusion of the precipitant leads to a compensation of errors.

The possibility of obtaining better results by using some derivative of barbituric acid will be discussed in the experimental part of this paper.

EXPERIMENTAL.

Barbituric acid ordinarily is prepared by the condensation of urea with the sodium salt of malonic ester. The corresponding thio derivative was prepared by Michael[16, 17] and by Gabriel and Colmann[18] by condensing thiourea with sodium malonic ester, and the imino derivative was prepared by Michael[17] and by Traube[19] from guanidine and malonic ester. These two derivatives are analogus in many respects to barbituric acid. It remained to be determined whether they would react in a similar manner with furfural, and possibly give a more complete precipitation.

The barbituric acid used in this work was a Kahlbaum preparation, which we purified further by recrystallization from water. Analysis showed it to contain 21.80 per cent nitrogen; theory 21.87 per cent.

Our first preparation of thiobarbituric acid was made according to the method of Gabriel and Colmann. Two and three-tenths gms. of sodium was dissolved in 50 cc. absolute alcohol, and 16 gms. malonic ester added, then 7.6 gms. dry thiourea, previously dissolved in absolute alcohol. The mixture was heated on a water bath under a reflux condenser for ten hours. The white pasty mass which resulted was then treated with 80 cc. water and 7.6 cc. hydrochloric acid and gently warmed until it had dissolved. Upon standing, thiobarbituric acid crystallized out. The yield was about 30 per cent of the theory. In preparing a further quantity of thiobarbituric acid we found that a much better yield was obtained when less solvent was used and the mixture heated for 15 hours in a sealed tube at 105°, with twice the theoretical amount of sodium, as recommended by Fischer and Dilthey[20] in their preparation of methylethyl and dimethylthiobarbituric acid. The product, after acidifying with hydrochloric acid, was a slightly yellowish crystalline powder containing 19.61 per cent nitrogen, whereas the theory calls for 19.45 per cent. The yield in this case was 45 per cent of the theory.

Malonylguanidine was made according to Traube from free guanidine and malonic ester. The condensation took place readily and gave an excellent yield. The product was used directly without further purification. It contained 32.07 per cent nitrogen; theory, 33.06 per cent.

Parallel determinations were now conducted, using barbituric acid, thiobarbituric acid and malonylguanidine as precipitants for furfural. For this work a stock solution of pure, freshly distilled furfural of exactly 1 per cent strength was prepared, and a 5 cc. aliquot taken for each determination. The furfural was diluted with 12 per cent hydrochloric acid and solutions of the different precipitants in 12 per cent hydrochloric acid added, the total volume of the reaction mixture being 400 cc. The conditions were, therefore, similar to those obtaining in pentosan determinations. Unless otherwise indicated, a slight excess of the precipitant was employed, the reaction carried out at room temperature, and the precipitate allowed to stand over night before filtering on Gooch crucibles and drying to constant weight at 100°. The analytical results are set forth in the following tables:

TABLE I.

BARBITURIC ACID.

Furfural Taken Gms.	Wt. of Precipitate Gms.	Furfural Calculated Gms.	Error Mgms.	Furfural Recovered Per Cent
.0583	.1180	.0550	— 3.3	94.3
.0583	.1180	.0550	— 3.3	94.3
.0583	.1171	.0546	— 3.7	93.6
.0583	.1174	.0547	— 3.6	93.8
.0583	.0976	.0455*	—12.8	78.0
.0583	.1194	.0556**	— 2.7	95.4
.0583	.1238	.0580***	— 0.3	99.5

*Precipitated with a little more than the theoretical amount of barbituric acid.

**Precipitated with 4 times the theoretical amount of barbituric acid.

***Precipitated with 16 times the theoretical amount of barbituric acid.

From the above table it is at once apparent that the results with barbituric acid are uniformly low. The last three determinations show the effect of increasing amounts of the precipitant. With barbituric acid and furfural in molecular proportions of sixteen to one, the result is nearly quantitative. This observation is in accord with statement of Unger and Jäger that eight times the theoretical amount of barbituric acid is necessary for complete recovery of the furfural.

TABLE II.

THIOBARBITURIC ACID.

Furfural Taken Gms.	Wt. of Precipitate Gms.	Furfural Calculated Gms.	Error Mgms.	Furfural Recovered Per Cent
.0583	.1351	.0584	+ 0.1	100.2
.0583	.1360	.0588	+ 0.5	100.8
.0583	.1372	.0593	+ 1.0	101.7
.0583	.1367	.0591	+ 0.8	101.4
.0583	.1361	.0588	+ 0.5	100.8
.0583	.1368	.0591	+ 0.8	101.4
.0583	.1271	.0550*	— 3.3	94.3
.0583	.1294	.0559*	— 2.4	95.9

*Precipitated at 60°.

With thiobarbituric acid, as shown in the above table, the precipitation is quantitative without using a large excess of the reagent. The results tend even to run just a trifle over the theory. The last two determinations above show that the reaction should not be allowed to occur at a high temperature since this leads to results that are too low.

TABLE III.

MALONYLGUANIDINE.

Furfural Taken Gms.	Wt. of Precipitate Gms.	Furfural Calculated Gms.	Error Mgms.	Furfural Recovered Per Cent
.0583	.0649	.0305	—27.8	52.3
.0583	.0640	.0300	—28.3	51.5

The condensation of furfural with malonylguanidine is not quantitative. The yield in the two determinations quoted above was only a little more than half the theory, hence under these conditions malonylguanidine is not applicable for the quantitative determination of furfural.

Having shown that thiobarbituric acid in moderate excess gives quantitative results under the conditions of the above experiments, whereas barbituric acid under the same conditions gives less than 95 per cent of the theoretical yield, it remains to compare these two reagents as regards their sensitiveness to smaller amounts of furfural. In the determinations recorded in table IV, four times the theoretical amount of barbituric acid was used.

TABLE IV.

BARBITURIC ACID.

Furfural Taken Gms.	Wt. of Precipitate Gms.	Furfural Calculated Gms.	Error Mgms.	Furfural Recovered Per Cent
.0117	none	none	no ppt.	none
.0117	.0061	.0028	— 8.9	26.5
.0233	.0225	.0105	—12.8	45.6
.0233	.0334	.0156	— 7.7	67.0
.0350	.0475	.0221	—12.9	63.1
.0350	.0640	.0298	— 5.2	85.1

It is obvious therefore, that the barbituric acid method is inapplicable to the determination of small quantities of furfural.

In table V, varying amounts of furfural are treated with varying amounts of thiobarbituric acid.

TABLE V.

THIOBARBITURIC ACID.

Furfural Taken Gms.	Thiobarbituric Acid Taken Gms.	Wt. of Precipitate Gms.	Furfural Calculated Gms.	Error Mgms.	Furfural Recovered Per Cent
.0592	.18	.1369	.0592	0.0	100.0
.0592	.18	.1398	.0603	+1.1	101.8
.0592	.18	.1370	.0592	0.0	100.0
.0592	.18	.1400	.0605	+1.3	102.3
.0592	.12	.1390	.0601	+0.9	101.6
.0592	.12	.1400	.0605	+1.3	102.3
.0592	.20	.1372	.0593	+0.1	100.2
.0360	.11	.0835	.0361	+0.1	100.3
.0360	.11	.0852	.0369	+0.9	102.5
.0244	.08	.0568	.0247	+0.3	101.2
.0244	.08	.0560	.0243	—0.1	99.6
.0244	.06	.0556	.0240	—0.4	98.3
.0244	.16	.0573	.0248	+0.4	101.6
.0119	.04	.0277	.0120	+0.1	100.8
.0119	.04	.0275	.0119	0.0	100.0
.0119	.03	.0261	.0113	—0.6	95.0
.0119	.08	.0278	.0120	+0.1	100.8

Here again, the results are just a trifle in excess of the theory. Even so small an amount of furfural as 12 mgms. gave practically a quantitative yield, and variations in the amount of precipitant were of very little influence.

Analysis of the condensation products showed the percentage of nitrogen to be in close agreement with the values calculated from the formulas.

TABLE VI.

ANALYSIS OF CONDENSATION PRODUCTS.

	Nitrogen		Sulphur	
	Found	Calculated	Found	Calculated
Furfuralmalonylurea	13.60	13.65	....	....
Furfuralmalonylthiourea	12.44	12.61	14.93	14.41
Furfuralmalonylguanidine ...	15.61	16.01	....	....

The furfuralmalonylurea is a bright lemon yellow, somewhat granular precipitate which settles readily. Furfuralmalonylthiourea is also a brilliant lemon yellow precipitate but very flocculent and voluminous. No difficulty was experienced in filtering and washing it, although the filtration was somewhat slow. It was practically insoluble in cold dilute mineral acids and only slightly soluble in hot acids. It was practically insoluble in alcohol, ether, petroleum ether, methyl alcohol, acetic acid, benzene, carbon disulphide and turpentine. In ammonia, pyridine and caustic alkalies it dissolves with ease, giving at first a greenish blue solution which gradually loses its color. From the alkaline solution it can be recovered by neutralizing with acid. The filtrates from both the furfuralmalonylurea and the furfuralmalonylthiourea had a very slight tinge of yellow. Furfuralmalonylguanidine, on the other hand, is a very dark green, flocculent precipitate, appreciably soluble in hydrochloric acid. The filtrate is an intense greenish brown.

It was early noted that unless the thiobarbituric acid was carefully purified, the precipitation of furfural was not complete, only 90 or 95 per cent of the latter being recovered, and the filtrate possessed a red color or sometimes a green color. In one set of determinations the difficulty was traced with reasonable certainty to the presence of cyanacetic ester in the malonic ester from which the thiobarbituric acid was made. In preparing malonic ester from chloracetic acid in the usual way, some cyanacetic ester is apt to remain unless precautions are taken to carry the saponification to completion. This is difficult to separate from the malonic ester because the boiling points of the two substances lie only a few degrees apart. The cyanacetic ester in all probability reacts with the thiourea, forming a dicyanacetylthiourea. On fractional crystallization of one of the impure preparations of thiobarbituric acid, white needle-shaped crystals were obtained, which on analysis yielded 26.66 per cent nitrogen; calculated for dicyandiacetylthiourea, 26.65 per cent nitrogen. These crystals when dissolved in 12 per cent hydrochloric acid gave an intensely green precipitate with furfural, just as did the thiobarbituric acid before purification. For the preparation of thiobarbituric acid it is, therefore, recommended that the malonic ester be subjected to a repetition of the simultaneous saponification and esterification before condensation with thiourea, and that the thiobarbituric acid be purified by one or two crystallizations of its sodium salt.

DISCUSSION.

Our experiments, quoted above, show that thiobarbituric acid condenses readily with furfural in the presence of 12 per cent hydrochloric acid. The reaction is quantitative, giving a voluminous precipitate which can be filtered, dried and weighed. As a precipitant for furfural, thiobarbituric acid is superior to phloroglucinol, in that no correction for solubility of the product is necessary. It is also preferable to barbituric acid for the reason that the reaction is quantitative with as small amounts of furfural as 12 mgms. and a large excess of the precipitant is not necessary, thus avoiding possible errors due to inclusion. Unlike the phloroglucinol product, the resulting furfuralmalonylthiourea is a definite substance resulting from the condensation of one molecule of furfural with one molecule of thiobarbituric acid by the elimination of one molecule of water, and a definite chemical formula can be assigned to it. It has a further advantage in that the percentages of nitrogen and sulphur, which agree with those calculated from the formula, can be determined by analysis and used as a positive means of identification of the product to distinguish it from, or detect the presence of, similar products which might result in case homologues of furfural were present. For example, if a mixture of furfural and methylfurfural were precipitated, the determinations of nitrogen and sulphur on the product should enable us to compute the relative amounts of these two aldehydes, and therefore the relative amounts of pentosans and methylpentosans in the original sample. At present the only means of estimating separately the furfural and methylfurfural present in a mixture such as is frequently met with in analysis, is the supposed differential solubility of their phloroglucides in alcohol, and this admittedly is unreliable.

It is suggested that thiobarbituric acid, which is not difficult to prepare in a pure state, may be found useful in the analysis of agricultural products, in place of phloroglucinol or barbituric acid, for the determination of pentoses and pentosans.

LITERATURE CITED.

(1) Günther, Chalmot & Tollens, Ber. 24, 3577 (1891).
(2) Stone, Ber. 24 3019 (1891).
(3) Flint and Tollens, Ber. 25, 2912 (1892).
(4) Jolles, Ber. 39, 96 (1906).
(5) Günther & Tollens, Ber. 23, 1751 (1890).
(6) Chalmot & Tollens, Ber. 24, 694 (1891).
(7) Councilor, Chem. Ztg. 17, 1743.
(8) Bureau of Chem. Bull. 107, p. 54 (1905).
(9) Kröber, J. Landw. 48, 357.
(10) Goodwin & Tollens, Ber. 37, 315 (1904).

(11) Kerp & Unger, Ber. 30, 590 (1897).
(12) Conrad & Reinbach, Ber. 34, 1339 (1901).
(13) Unger & Jäger, Ber. 35, 4440 (1902); 36, 1222, (1903).
(14) Fromherz, Z. physiol. Chem. 50, 241 (1910).
(15) Fallada, Stein & Ravinka, Oesterr. ung. Z. Zuckerind 43, 425.
(16) Michael, J. prakt. Chem. 35, 456 (1887).
(17) Michael, J. prakt. Chem. 49, 37 (1894).
(18) Gabriel & Colmann, Ber. 37, 3657 (1904).
(19) Traube, Ber. 26, 2553 (1893).
(20) Fischer & Dilthey, Ann. 335, 350 (1904).

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ELECTROMOTIVE FORCES AND ELECTRODE POTENTIALS IN PYRIDINE AND ITS BINARY MIXTURES WITH WATER, METHYL ALCOHOL AND ETHYL ALCOHOL.

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HISTORICAL.

The systematic study of the electromotive forces in non-aqueous solvents was begun by Jones.[1] By using cells of the type:

$$Ag—AgNO_3\,aq.————AgNO_3\,non\text{-}aq.—Ag$$

with the same concentration of the salt in each solvent, he hoped to be able to calculate the degree of dissociation in the non-aqueous solutions. It soon became apparent, however, that the solution pressure of a metal varies from solvent to solvent. Substituting the values found by Völlmer[2] for the degree of dissociation of silver nitrate in ethyl alcohol, he calculated the ratio of the solution pressure of silver in alcohol and in water to be between 0.021 and 0.024. In all of these measurements the alcoholic solutions are positive with respect to the water solutions.

Kahlenberg[3] measured the electrode potential of ten different metals in 0.10 N solutions of their salts in about thirty solvents. The electrodes dipped into the solutions which were contained in open vessels, connection between the cells being made by strips of filter paper. The diffusion potential was neglected and apparently no definite temperature was maintained. From his results, which he stated were only qualitative in nature, he concluded that the solution pressure varies not only with the different solvents and their mixtures, but also with the nature of the dissolved substances. He also tested and found that Faraday's laws hold for non-aqueous solutions.

Wilson[4] measured the electromotive forces of concentration cells in alcoholic solutions of silver nitrate at both 0° and 25°. While the values of the electromotive forces calculated from conductivity data deviated somewhat from those experimentally determined, he concluded that the Nernst equation will be found to hold as well as in non-aqueous solutions.

[1]Zeit. physik. Chem., 14, 346, 1894.
[2]Dissertation, Halle, 1892.
[3]Jour. Physical Chem., 3, 379, 1899.
[4]Am. Chem. Jour., 35, 78, 1906.

Neustadt and Abegg[5] investigated the electrode potentials and electromotive forces of a number of cells containing solutions of the salts of silver, lead, copper, mercury, cadmium, and zinc. The solvents used were water, methyl alcohol, ethyl alcohol, acetone, and pyridine. In all cases the half cell, Ag-$AgNO_3$—, constituted one-half of the cell. Since the potential differences in methyl alcohol, ethyl alcohol and acetone are approximately equal to those in water, they concluded that the solution pressures of any one of the metals in these four solvents are approximately equal. The considerably lower values obtained for solutions in pyridine are attributed to extremely low ionic concentration. They also consider that, possibly, silver nitrate is ionized in pyridine solution according to the equation:

$$Ag_2(NO_3)_2 \rightleftarrows Ag_2 \overset{+}{NO_3} + \overset{-}{NO_3}$$

Experiments were made using a number of solution chains as liquid junctions in an attempt to eliminate the diffusion potential.

Getman[6] and Getman and Gibbons[7] measured the potentials of cadmium and zinc in alcoholic solutions of their salts. In each case the normal calomel electrode constituted the other half of the cell. For both metals it was found that the electrode potentials become more negative as the concentration of the salt increases. Since the effect of concentration is just the reverse of what is found for aqueous solutions, they concluded that the applicability of the Nernst equation is very improbable.

Bell and Field[8] measured the electromotive forces of concentration cells in water and in ethyl alcoholic solutions of silver nitrate. Rearranging the Nernst equation to the form:

$$\frac{\pi}{\log_{10} \frac{c}{c_2}} = \frac{2v}{u+v} \cdot \frac{RT.}{nf} \log_e 10 = K$$

they calculated the values of K. The values thus obtained varied between 0.0560 and 0.0623. Assuming the value 0.0623, they calculated the transport number of the anion of silver nitrate in water to be 0.523. Since, however, the value of K varies so widely, they concluded that the transport number must change with the concentration of the salt.

[5]Zeit. physik. Chem., 69, 486, 1909.
[6]Am. Chem. Jour., 46, 117, 1911.
[7]Ibid., 36, 1630, 1914.
[8]Jour. Am. Chem. Soc., 35, 715, 1913.

Getman and Gibbons[9] measured the electrode potentials, transport numbers and conductivities in solutions of silver nitrate in methyl alcohol, ethyl alcohol, acetone, and aniline. They concluded that certain abnormalities in non-aqueous solutions may be attributed to the formation of complex solute-solvent compounds which dissociate more or less gradually with the dilution.

The first systematic study of electrode potentials and electromotive forces in mixed solvents was reported by Pearce and Farr.[10] They determined the electromotive forces of concentration cells and the electrode potentials of silver against its ions in water, methyl alcohol and ethyl alcohol and in their binary mixtures at both 0° and 25°. From the close agreement between the observed and calculated values of the electromotive forces it was shown that the Nernst equation can be applied not only to solutions in non-aqueous solvents, but also to solutions in binary mixtures of these solvents. The electrode potentials are relatively greatest in methyl alcohol and least in aqueous solutions, the corresponding values in ethyl alcohol occupying an intermediate position. Further, the values of the electrode potentials are highest in the most concentrated solutions. In all cases they decrease rapidly with dilution at first and then subsequently the decrease proceeds almost linearly with further dilution.

The electrode potentials in the binary mixtures of the alcohols obey the law of mixtures. In the binary mixtures of water and the two alcohols, the electrode potentials increase slowly at first with addition of alcohol from the value in pure water up to mixtures containing about seventy-five per cent of the alcohol and then more rapidly with further increase in the proportion of the alcohol.

The temperature coefficients of the electrode potentials are positive for solutions in both alcohols and their binary mixtures. Those in ethyl alcohol and the aqueous mixtures containing seventy-five per cent and fifty per cent ethyl alcohol, increase with dilution throughout, while those in methyl alcoholic solutions pass through a minimum value. The temperature coefficients in the water and the seventy-five per cent aqueous mixtures are negative throughout, becoming more negative with increasing dilution. The influence of the water as manifested by the temperature coefficients of the electrode potentials is displaced toward higher dilutions as the proportion of the alcohol in the mixture is increased.

[9] Ibid. 36, 1630, 1914.
[10] Jour. Physical Chem., 18, 729, 1914.

They also determined the solution pressure of silver in each of the three solvents, as well as the heats of ionization for the pure solvents and their fifty per cent binary mixtures.

In the hope that still further light may be thrown upon the influence of solvent upon the electrochemistry of solutions, a fourth solvent, pyridine, has been added to the series. To those who are familiar with pyridine and its properties, little need be said. Unlike the three hydroxy-compounds of the previous work, its molecule has the ring structure with one nitrogen atom in the ring. For many salts it is an excellent solvent and the solution of these salts in pyridine is accompanied by a very considerable evolution of heat. Silver nitrate, like many of these salts, separates from its solution in pyridine with pyridine of crystallization; its power to form solvates of high complexity is, therefore, obvious. Of the four solvents named, pyridine has the smallest dielectric constant, yet with many salts it gives solutions possessing fairly good electrical conductivity.

In the present work the electromotive forces of concentration cells and the electrode potentials of silver against solutions of its ions have been redetermined for solutions of the metal in water and the two alcohols at 0° and 25°. Further, similar data have been obtained for solutions of silver nitrate in pure pyridine and for its binary mixtures with water, methyl alcohol and ethyl alcohol, respectively.

MATERIALS AND SOLUTIONS.

Water—The water used was prepared according to the method of Jones and Mackay[11]. Repeated measurements showed it to have a specific conductivity of approximately 2.0×10^{-6} mhos.

Ethyl Alcohol—Ordinary 95 per cent alcohol was allowed to stand over fresh quicklime for two or three weeks. It was then decanted and distilled. The distillate was allowed to stand over anhydrous copper sulphate for one week and then redistilled. This distillate was refluxed with metallic calcium for ten hours and again distilled. Finally, it was refluxed for two hours with silver nitrate to remove aldehydes and other reducing agents. The distillate from this treatment was collected and preserved in dry glass-stoppered bottles, being protected from the air during distillation by phosphorus pentoxide tubes. In each distilla-

[11]Am. Chem. Jour., 19, 83, 1897.

tion a fractionating column was used and only that middle portion which passed over between 77.9° and 78° (uncorr.) was used.

Methyl Alcohol.—Kahlbaum's best grade of alcohol was further purified in the same manner as the ethyl alcohol, except that the treatment with quicklime was omitted. Only that distillate passing over between 64.9° and 65.1° (uncorr.) was used.

Pyridine.—The best grade of pyridine obtainable was allowed to stand over fused potassium hydroxide for two weeks. It was then decanted and distilled. That portion passing over between 115.3° and 115.4° was collected and preserved in dry glass-stoppered bottles, protected during distillation by a train of phosphorus pentoxide and calcium chloride tubes. Because of its great absorptive power for water, extraordinary care was used in handling the pyridine.

Silver Nitrate.—Baker's "Analyzed" silver nitrate was recrystallized by the rapid cooling of a hot saturated solution of the salt in conductivity water. The crystals were filtered on a Büchner funnel, washed with ice-cold conductivity water, sucked dry, and then heated for several hours in a toluol bath at 109°. The salt when thoroughly dry was kept in dark bottles further protected by dark cloths.

Potassium Chloride.—Baker's "Analyzed" potassium chloride was further purified by precipitating a saturated solution by hydrogen chloride gas. The precipiate was filtered on a Büchner funnel, washed with conductivity water, heated to dryness in an air bath at 110° and the crystals preserved in a desiccator over phosphorus pentoxide. The salt was always strongly heated before using.

Mercury.—The mercury was repeatedly washed with dilute nitric acid and the acid removed by repeated washing with conductivity water. It was then distilled under reduced pressure in a current of air.

Calomel.—Kahlbaum's best grade of mercurous chloride was repeatedly washed with a 0.10 N potassium chloride solution after which it was preserved under a fresh sample of the same solution in dark bottles.

Solutions.—All solutions were prepared by direct weighing, or by the suitable dilution of freshly prepared solutions. They were made up to volume at 25° and, to avoid the possibility of any decomposition occurring in the solutions, all electrometric measurements were made on the same day.

Mixtures.—The solvent mixtures were made up on a percentage basis by weight, the weights of the separate components being accurate to 0.1 gram per liter.

APPARATUS.

The apparatus used in this work was the same as that used by Farr.[12] The constant temperature baths consisted of large deep metal boxes inclosed within larger wooden boxes, the space between being filled with insulating material. The 0°-bath was obtained by clean finely crushed ice moistened with distilled water. The water in the 25°-bath was kept in rapid circulation by a mechanical stirrer. It was electrically heated and maintained at 25° ± .01 by an electrically controlled temperature regulator.

Seven half-cells and two calomel electrodes were used in this investigation. Each half-cell was fitted with a stop-cock in the connecting tube. These were always kept closed except when measurements were being made. Loose plugs of filter paper inserted in the ends of the connecting tubes practically eliminated any possible diffusion potential even when the stop-cocks were momentarily opened for potential readings. The middle vessel was so arranged that the connecting tubes of all the cells could be inserted through tight-fitting rubber stoppers. With this arrangement the solutions were not unduly exposed to the air and the measurements could be made on any combination by simply changing the wire leads and opening the stop-cocks in the connecting tubes. A normal aqueous solution of ammonium nitrate was used in the middle vessel. It was assumed that this solution eliminates the diffusion potential.[13]

The calomel electrodes were prepared in the following manner. In the bottom of the electrode vessel was placed a large globule of pure mercury. This was next covered by a calomel paste prepared by intimately mixing calomel and mercury moistened with 0.1 N solution of potassium chloride. Over this was placed a solution of the 0.1 N potassium chloride which had been shaken with

[12] Loc. cit.
[13] Ostwald-Luther: Messungen, 3d Ed., p. 448.

calomel and allowed to stand in contact with it until saturated. The single potential of the calomel electrode was calculated from the value given by Richards,[14] the values taken being +0.5986 volts at 0° and +0.6186 volts at 25°. These electrodes were renewed alternately every two weeks and were found to be reproducible to within two-tenths of a millivolt.

The electromotive forces were measured by means of a Wolff potentiometer in connection with a Leeds-Northrup, "Type H," wall galvanometer. In aqueous solutions it was easily sensitive to .01 millivolt, but the high resistance in non-aqueous solutions made it almost impossible to detect differences of less than 0.1 millivolt. A Cadmium-Weston cell which had been recently standardized against a similar element certified by the Bureau of Standards was used as the standard of reference. It had an electromotive force of 1.01745 volts of 25°. While its temperature coefficient is practically negligible, it was kept at this temperature by insulating it in a beaker immersed in the 25°-bath.

The silver electrodes were prepared according to the method described by Farr.[15] Short pieces of pure silver wire were fused into the ends of glass tubes. To the ends sealed into the glass were soldered copper wires, each the length of the glass tube. The tubes were then filled to within an inch of the top with hard paraffine which prevented the mercury with which the contact was made with the wire leads, from amalgamating the silver. Before being used the electrodes were plated by connecting them in series in a solution of potassium-silver cyanide. After a current of ten milliamperes had been passed for three hours, they were removed, rinsed with distilled water and allowed to stand for forty-eight hours in contact with a button of pure silver under a pure aqueous solution of silver nitrate. Ten or twelve electrodes were thus prepared. The choice of the electrodes was made in the following manner. They were all grouped in a single cell containing a 0.1 N solution of silver nitrate which was in turn connected with a calomel electrode through an intermediate solution of ammonium nitrate. Only those electrodes were chosen which gave an electromotive force varying not more than 0.1 millivolt from 0.3886 volts.

It was observed early in the work that the electrode potential of a freshly prepared half-cell changes on standing. This

[14] Zeit. physik. Chem., 24, 39, 1897.
[15] Loc. cit.

change, for any given electrode, is most rapid at first, the rate of change then gradually decreasing to zero at equilibrium. In order to eliminate any errors from this source, the whole battery of half-cells with their respective electrodes and solutions was set up and allowed to stand for at least one and one-half hours at constant temperature. That this time sufficed for the attainment of equilibrium betwen electrode and solution may be seen from the following table:

Time	30	60	75	90	105 min.
Electrode potential....	.6559	.6571	.6577	.6578	.6578 volts

THEORETICAL.

There are four sources of electromotive force in any cell: the thermo-electric potential at the junction of the wire leads with the electrodes, the diffusion potential at the junction of the two solutions, and the electrode potentials at the surfaces of contact between the electrodes and their respective solutions. The first is entirely eliminated by compensation, and it is assumed that the diffusion potential has been made negligible by the interposition of the 0.1 N solution of ammonium nitrate. There is left for consideration, therefore, only the two electrode potentials.

According to the equation of Nernst, based on the osmotic theory of the cell, the electrode potentials of a metal in contact with two solutions of its ions are given by the expressions:

$$\pi_2 = \frac{RT}{nf} \cdot \ln \frac{P}{p_2} \text{ and } \pi_1 = \frac{RT}{nf} \cdot \ln \frac{P}{p_1} \cdot \qquad (1)$$

where R represents the gas-constant, (1.985 calores), T the absolute temperature, n the valence of the cation, and f the faraday (96540 coulombs), P represents the solution pressure of the metal, and p_1 and p_2 the osmotic pressures of the cation in the two solutions, the pressure being measured in atmospheres.

Assuming the absence of a diffusion potential, the electromotive force of a concentration cell is therefore given by the expression:

$$\pi = \pi_2 - \pi_1 = \frac{RT}{nf} \cdot \ln \frac{P}{p_2} - \frac{RT}{nf} \cdot \ln \frac{P}{p_1}, \text{ — } (p_1 > p_2).$$

This by rearrangement becomes,

$$\pi = \frac{RT}{nf} \cdot \ln \frac{p_1}{p_2} \qquad (2)$$

Since the osmotic pressures of the ions are proportional to their concentrations and since for normal electrolytes the concentrations are in turn proportional to the equivalent conductivities of the solutions, then

$$\frac{p_1}{p_2} = \frac{\alpha_1 c_1}{\alpha_2 c_2} = \frac{\lambda_1 c_1}{\lambda_2 c_2}.$$

Substituting in (2), we have

$$\pi = \frac{RT}{nf} \cdot \ln \frac{\lambda_1 c_1}{\lambda_2 c_2}, \qquad (3)$$

where c, α and λ represent the concentration, the degree of dissociation and the equivalent conductance of the electrolyte, respectively.

The temperature coefficients of the electrode potentials were calculated by means of the relation,

$$\frac{d\pi}{dT} = \frac{\pi_{25} - \pi_0}{\pi_0 \cdot 25}. \qquad (4)$$

The relation between the electrical and chemical energies in a cell is given by the well-known Helmholtz equation,

$$\pi = \frac{Q}{f} + T\frac{d\pi}{dT}.$$

By rearranging and multiplying by .2387 in order to convert joules into calories

$$Q = f\left(\pi - T\frac{d\pi}{dT}\right) \cdot .2387, \qquad (5)$$

where Q is the heat of ionization.

By rearranging (1), the solution pressure of a metal is given by the expression,

$$\ln P = \frac{\pi nf}{RT} + \ln p.$$

By substituting for the osmotic pressure p its value calculated from the gas laws, i. e.,

$$p = 22.4 \cdot \alpha \cdot c \cdot \frac{T}{273},$$

there is obtained for the solution pressure of the metal, the relation

$$\ln P = \frac{\pi nf}{RT} + \ln\left(22.4 \cdot \alpha \cdot c \cdot \frac{T}{273}\right). \qquad (6)$$

RESULTS.

The results obtained are given in the following tables and curves:

TABLE I.

Electrode Potentials in Water-Pyridine Series at 25°.

N	100 Water volts	75 W-25 P volts	50 W-50 P volts	25 W-75 P volts	100 Pyridine volts
1.0	1.0513	------------	.7513	.7002	.6112
.50	1.0430	.7603	.7026	.6496	.5866
.10	1.0097	.7075	.6578	.6070	.5470
.05	.9944	.6820	.6371	.5878	.5367
.025	.9774	.6650	.6178	.5714	.5255
.01	.9578	.6426	.6023	.5504	.5055
.005	.9403	.6343	.5928	.5328	.4853

TABLE II.

Electrode Potentials in Water-Pyridine Series at 0°.

N	100 Water volts	75 W-25 P volts	50 W-50 P volts	25 W-75 P volts	100 Pyridine volts
1.0	1.0456	------------	.7282	.6836	.5810
.50	1.0411	.7382	.6842	.6361	.5678
.10	1.0095	.7034	.6324	.5946	.5296
.05	.9913	.6739	.6258	.5758	.5216
.025	.9820	.6571	.6085	.5630	.5081
.01	.9625	.6405	.5973	.5421	.4926
.005	.9471	.6334	.5866	5309	.4746

Mean Temperature Coefficients of Electrode Potentials.

	—.000045	+.000430	+.000762	+.000771	+.001293

TABLE III.

Concentration Cells in Water-Pyridine at 25°.

N_1-N_2	100 Water	75 W-25 P	50 W-50 P	25 W-75 P	100 Pyridine
1. —.1	.042	------------	.094	.093	.065
.05	.057	------------	.114	.112	.074
.025	.074	------------	.134	.129	.086
.01	.093	------------	.149	.150	.104
.005	.111	------------	.159	169	.126
.1 —.05	.015	.025	.021	.019	.010
.025	.032	.042	.039	.039	.021
.01	.052	.065	.055	.056	.039
.005	.069	.074	.065	.077	.062
.05 —.025	.017	.017	.020	.016	.011
.01	.037	.039	.035	.037	.030
.005	.054	.049	.045	.055	.052
.025—.01	.019	.022	.015	.021	.019
.005	.037	.031	.024	.038	.041
.01 —.005	.017	.008	.010	.021	.022

TABLE IV.

Concentration Cells in Water-Pyridine at 0°.

N_1-N_2	100 Water	75 W-25 P	50 W-50 P	25 W-75 P	100 Pyridine
1. —.1	.036	------------	.096	089	.051
.05	.054	------------	.090	.107	.059
.025	.064	------------	.119	.120	.073
.01	.083	------------	.131	.142	.088
.005	.098	------------	.142	.153	.105
.1 —.05	.018	.030	.003	.018	.008
.025	.027	.046	.025	.031	.021
.01	.047	.063	.034	.052	.037
.005	.062	.072	.046	.064	.051
.05 —.025	.009	.017	.027	.013	.013
.01	.029	.033	.036	.035	.029
.005	.044	.041	.048	.045	.047
.025—.01	.019	.016	.009	.021	.016
.005	.035	.024	.021	.033	.033
.01 —.005	.015	.007	.012	.011	.018

TABLE V.

Electrode Potentials in Ethyl Alcohol-Pyridine Series at 25°.

N	100 Ethyl volts	75 E-25 P volts	50 E-50 P volts	25 E-75 P volts	100 Pyridine volts
.5	------------	.7986	.6872	.6380	.5866
.1	1.0826	.7348	.6391	.5921	.5470
.05	1,0686	.7084	.6222	.5790	.5367
.025	1.0592	.7007	.6148	.5655	.5255
.01	1.0391	.6821	.5906	.5363	.5066
.005	1.0277	.6684	.5667	.5204	.4853

TABLE VI.

Electrode Potentials in Ethyl Alcohol-Pyridine Series at 0°.

N	100 Ethyl volts	75 E-25 P volts	50 E-50 P volts	25 E-75 P volts	100 Pyridine volts
.5	------------	.7698	.6621	.6190	.5678
.1	1.0696	.7144	.6195	.5741	.5293
.05	1.0571	.6866	.6036	.5603	.5216
.025	1.0466	.6739	.5952	.5473	.5081
.01	1.0251	.6583	.5726	5108	.4920
.005	1.0131	.6397	.5512	.5083	.4746

Mean Temperature Coefficients of Electrode Potentials.

	+.000506	+.001457	+.001280	+.001295	+.001293

TABLE VII.

Concentration Cells in Ethyl Alcohol and Pyridine at 25°.

N_1-N_2	100 Ethyl	75 E-25 P	50 E-50 P	25 E-75 P	100 Pyridine
0.5 —.1	------------	.064	.048	.046	.039
.05	------------	.090	.065	.059	.050
.025	------------	.099	.073	.073	.061
.01	------------	.116	.097	102	080
.005	------------	.130	.121	117	.101
0.1 —.05	.014	.026	.017	.013	.010
.025	.024	.034	.024	.027	.021
.01	.043	.052	.049	.056	.039
.005	.055	.066	.072	.071	.062
.05 —.025	.010	.008	.007	.013	.011
.01	.029	.026	.032	.043	.030
.005	.041	.040	.055	.058	.052
.025—.01	.031	.018	.024	.029	.019
.005	.032	.032	.048	.044	.041
.015—.005	.012	.014	.024	.016	.022

TABLE VIII.

Concentration Cells in Ethyl Alcohol and Pyridine at 0°.

N_1-N_2	100 Ethyl	75 E-25 P	50 E-50 P	25 E-75 P	100 Pyridine
0.5 —0.1	-----------	.055	.042	.045	.038
.05	-----------	.087	.058	059	.046
.025	-----------	.096	.067	.072	.060
.01	-----------	.112	.089	.109	.075
.005	-----------	.130	.111	.111	.093
0.1 — .05	.013	.031	.016	.014	.008
.025	.023	.040	.024	.027	.021
.01	.044	.056	.047	.063	.037
.005	.056	.074	.069	.066	.055
.05 — .025	.010	.009	.008	.013	.013
.01	.032	.025	.031	.049	.029
.005	.044	.043	.053	.052	.047
.025— .01	.020	.016	.022	.036	.016
.005	.034	.034	.044	039	.033
.01 — .005	.012	.018	.022	.003	.018

TABLE IX.

Electrode Potentials in Methyl Alcohol-Pyridine Series at 25°.

N	100 Methyl volts	75 M-25 P volts	50 M-50 P volts	25 M-75 P volts	100 Pyridine volts
.5	------------	.8105	.7177	.6386	.5866
.1	1.0975	.7306	.6541	.5911	.5470
.05	1.0799	.7145	.6369	.5690	.5367
.025	1.0707	.6959	.6201	.5520	.5255
.01	1.0507	.6766	.6000	.5426	.5066
.005	1.0286	.6612	.5834	.5280	.4853

TABLE X.

Electrode Potentials in Methyl Alcohol-Pyridine at 0°.

N	100 Methyl volts	75 M-25 P volts	50 M-50 P volts	25 M-75 P volts	100 Pyridine volts
.5	------------	.7811	.6934	.6175	.5678
.1	1.0916	.7126	.6233	.5658	.5296
.05	1.0706	.6970	.6184	.5522	.5216
.025	1.0611	.6814	.6017	.5369	.5081
.01	1.0330	.6628	.5851	.5243	.4926
.005	1.0167	.6493	.5614	5120	.4746

Mean Temperature Coefficients of Electrode Potentials.

	+.000368	+.00098	+.001419	+.001352	+.001293

TABLE XI.

Concentration Cells in Methyl Alcohol and Pyridine at 25°.

N_1-N_2	100 Methyl	75 M-25 P	50 M-50 P	25 M-75 P	100 Pyridine
.5 —.1	-----------	.080	.064	.047	.039
.05	-----------	.096	.081	.069	.050
.025	-----------	.115	.098	.087	.061
.01	-----------	.134	.117	.096	.080
.005	-----------	.149	.134	111	.101
.1 —.05	.018	.016	.017	.021	.010
.025	.027	.035	.035	.039	.021
.01	.047	.054	.054	.049	.039
.005	.069	.069	.072	.063	.062
.05 —.025	.010	.018	.017	.017	.011
.01	.030	.038	.037	.027	.030
.005	.052	.053	.054	.041	.052
.025—.01	.020	.019	.020	.009	.019
.005	.042	.035	.037	.024	.041
.01 .005	.022	.015	.017	.014	.022

TABLE XII.

Concentration Cells in Methyl Alcohol and Pyridine at 0°.

N_1-N_2	100 Methyl	75 M-25 P	50 M-50 P	25 M-75 P	100 Pyridine
.5 —.1	-----------	.068	.070	.052	.038
.05	-----------	.084	.075	.065	.046
.025	-----------	.099	.092	.081	.060
.01	-----------	.118	.107	093	.075
.005	-----------	.132	.131	.106	.093
.1 —.05	.021	.016	.005	.013	.008
025	.031	.031	.021	.028	.021
.01	.059	.050	.038	.041	.037
.005	.075	.063	.062	.054	.054
.05 —.025	.010	.015	.016	.015	.013
.01	.037	.034	.033	.028	.029
.005	.053	.047	.058	.040	.047
.025—.01	.028	.019	.016	.012	.016
.005	.044	.032	.041	.015	.033
.01 —.005	.017	.014	.025	.012	.018

TABLE XIII.

Concentration Cells in Pure Pyridine.

N_1-N_2	Observed 0°	Calculated	Observed 25°	Calculated
1.0 — 0.1	+.051	—.021	+.065	—.015
.05	+.059	—.005	+.074	+.0001
.01	+.088	+.032	+.101	+.037
.5 —0.1	+.038	+.031	+.039	+.033
.05	+.046	+.046	+.050	+.049
.01	+.075	+.084	+.080	+.086
.1 —.05	+.008	+.015	+.010	+.015
.01	+.037	+.053	+.039	+.052
.05— .01	+.029	+.037	+.030	+.037

TABLE XIV.

Heats of Ionization.

Solvent	Electrode Potential	Mean of the Temp. Coeff.	Heat of Ionization	Dielectric Constant
100 water	1.0097	—.000069	23728	80.5
75 W—25 P	.7075	+.000430	13352	56.9
50 W—50 P	.6578	+.000762	9925	41.1
25 W—75 P	.6070	+.000691	9243	31.5
100 Pyridine	.5470	+.001293	3726	11.2
100 Ethyl	1.0826	+.000506	21472	----------
75 E—25 P	.7348	+.001457	6927	----------
50 E—50 P	.6391	+.001280	5938	----------
25 E—75 P	.5921	+.001354	4346	----------
100 Methyl	1.0975	+.000415	22440	32.8
75 M—25 P	.7306	+.000989	10045	24.5
50 M—50 P	.6541	+.001420	5321	18.2
25 M—75 P	.5911	+.001356	4310	----------

TABLE XV.

Solution Pressures in the Pure Solvents.

Solvent	Solution Pressure
Water	2.46×10^{-17}
Ethyl Alcohol	2.02×10^{-18}
Methyl Alcohol	3.55×10^{-19}
Pyridine	1.77×10^{-10}

DISCUSSION.

The observed electromotive forces of all the possible concentration cells of the type:

$$Ag—AgNO_2,c_1—1.0\ N\ NH_4NO_3—AgNO_3,c_2—Ag$$

may be found in Tables III, IV, VII, VIII, XI and XII. The observed values are small, as we should expect. While they are incumbered, doubtless, with slight errors, they are approximately of the right order of magnitude. In all cases the positive electrode was found in the more concentrated solution. Conductivity data are not available for the solutions in the binary mixtures containing pyridine as one of the components. It is therefore impossible to give the calculated values in the mixed solvents. In the pure solvents, water, methyl alcohol, and ethyl alcohol, the values obtained agree closely with those obtained by Farr,[16] thus confirming his statement that the Nernst equation does hold for concentration cells in these solvents.

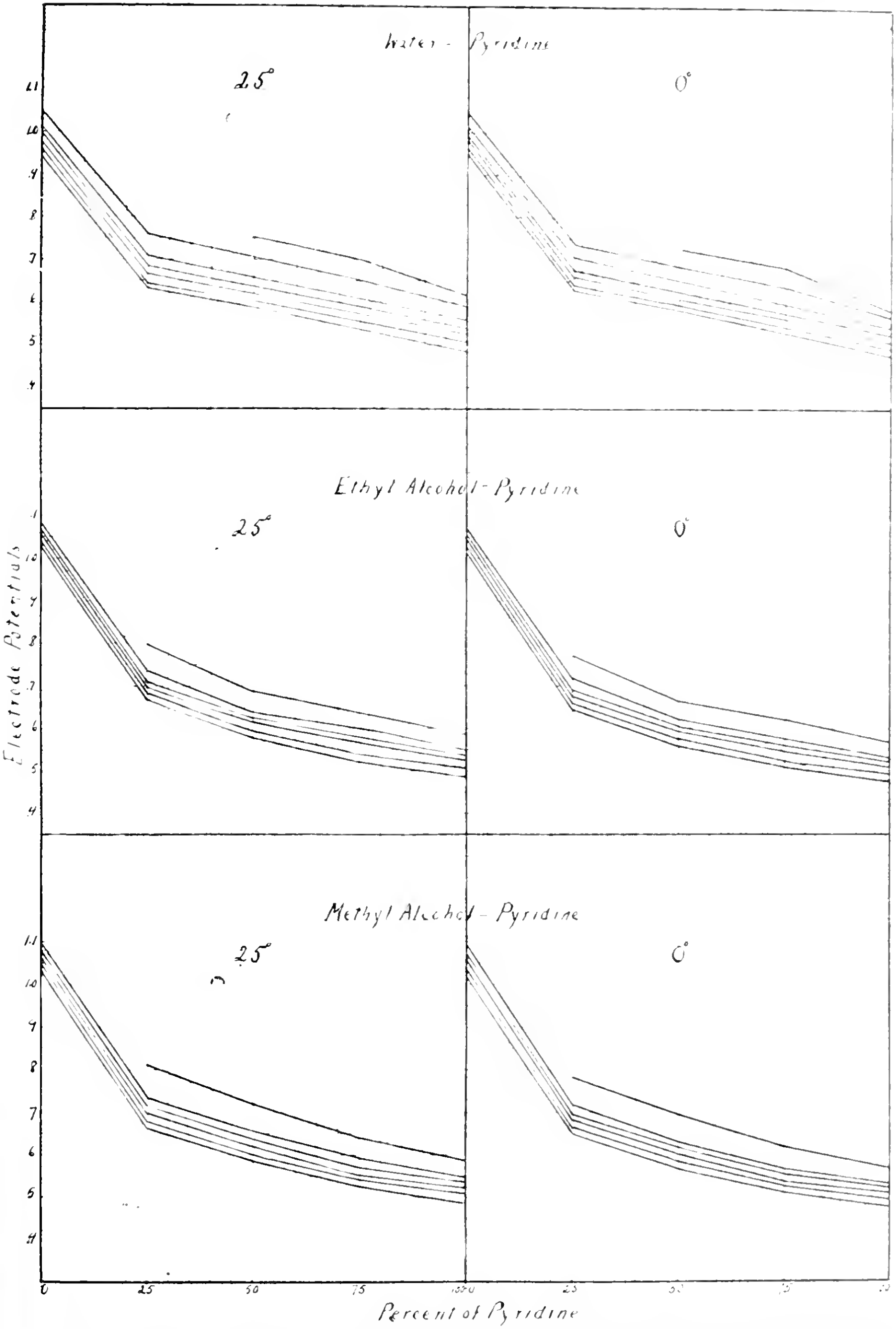
During the present year the equivalent conductances of solutions of silver nitrate in pure pyridine have been carefully determined by Mr. H. L. Dunlap of this laboratory. Repeated determinations give the following values for the equivalent conductance at infinite dilution:

λ_∞ at $0^\circ = 51$, λ_∞ at $25^\circ = 71$.

In attempting to calculate the electromotive forces of concentration cells in pyridine from Mr. Dunlap's conductivity data, it was found that the calculated values deviate considerably from those observed. They are peculiar in the following respects: When the normal solution constitutes one-half of the concentration cell they are smaller than the observed values, but if the concentrations in each of the half-cells are less than .5 N they are larger. Furthermore, it will be observed that with the more concentrated solutions the calculated electromotive forces show reversal of sign.

The deviations between the observed and calculated values for the electromotive forces of concentration cells in pure pyridine must be attributed to one or both of two causes,—either the solution pressure of the metal varies with the concentration of the dissolved silver nitrate, or, owing to polymerization and subsequent ionization, the equivalent conductivity is not a true

[16]Loc. cit.



Curves showing the influence of pyridine upon the electrode potentials of silver against solutions of silver ions in water, methyl alcohol, ethyl alcohol and pyridine, and in the binary solvents containing pyridine as one component. The upper curve in each plot represents the most concentrated solution.

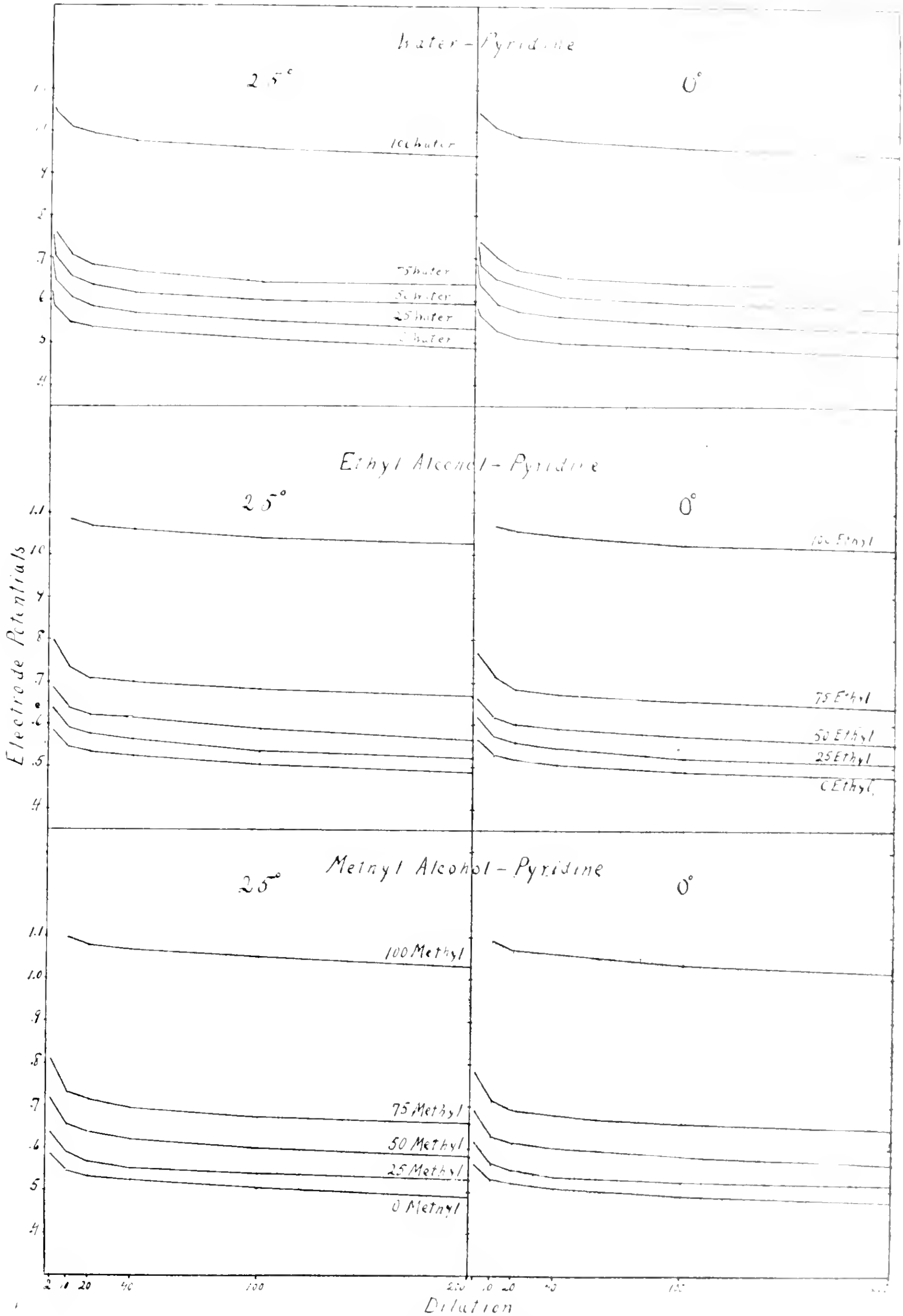
measure of the concentration of the silver ions. The latter alternative is in accord with the observation of Neustadt and Abegg[17] that in the electrolysis of pyridine solutions of silver nitrate both the silver ion and the nitrate radicle migrate to the cathode, probably as a complex ion.

Walden and Centnerszwer[18] have found that the molecular weight of silver nitrate in dilute pyridine solutions is normal, while in the more concentrated solutions it is greater than normal, thus indicating association. Since simple silver ions must be present, if an electromotive force is to exist, it is probable that silver nitrate may ionize both as simple and as complex ions. If the ionization of the complex molecule is just sufficient to form as many particles as there would be if the substance existed as a simple molecule, then the molecular weight should appear to be normal. This is probably the case in the more dilute solutions of silver nitrate in pyridine.

It is evident from Tables I, II, V, VI, IX, X and from Plate II A that the electrode potentials of silver are much higher for solutions in water, methyl alcohol and ethyl alcohol than for equivalent concentrations in pyridine. On comparing the equivalent concentrations, it will be observed that for all binary mixtures of pyridine with water and with the two alcohols the electrode potential increases with the decrease in the proportion of pyridine in the mixture. This increase is very gradual until seventy-five per cent of the pyridine has been replaced by the second solvent. For the water-pyridine mixtures the initial increase is apparently a linear function of the per cent of water present. With further decrease in the proportion of pyridine there is a rapid increase in the value of the electrode potential to its value in the second solvent. The curves for the water-pyridine series show a strong resemblance to the curve found by Hartley, Thomas and Appleby[19] for the surface tensions of the same system. Whether or not any relation exists between surface tension and electrode potential is a question still unanswered.

For all solvents, simple and mixed, the electrode potentials increase as the concentration of the salt increases. From the curves, Plate II B, it will be observed that, starting with the most

[17]Loc. cit.
[18]Zeit. physik. Chem., 55, 321, 1906.
[19]Trans. Chem. Soc., 93, 549, 1908.



Curves showing the relation between the electrode potentials and the concentration of the silver nitrate in the pure and binary solvents.

concentrated solution, the electrode potential drops very rapidly with the first dilutions, and then decreases almost linearly in the more dilute regions. It will also be observed from the volume-electrode potential curves for any set of binary mixtures and hence for all of the pure solvents as well, that the curves obtained are practically parallel to each other. If they were exactly parallel, it would follow, as was stated by Farr,[20] that, "if the electromotive force at the junction of the two solutions has been entirely eliminated, and since the electromotive force of a concentration cell at a given temperature is proportional to the logarithm of the ratio of the ionic concentrations in the two solutions, it follows that the ratio between the ionic concentrations for equivalent concentrations of the salt in the separate solvents is constant and independent of the dilution."

The mean temperature coefficient of the electrode potentials in each solvent has been calculated for both the pure solvents and their mixtures and tabulated at the bottom of the tables for the electrode potentials. All of the temperature coefficients are positive except those in the more dilute solutions in the pure water. In all solutions containing pyridine the temperature coefficients are extremely large. In the water-pyridine series they increase continually from the value in pure water to the value in pure pyridine as the per cent of pyridine is increased. In the ethyl alcohol-pyridine solutions they increase rapidly with the first addition of pyridine, then decrease to practically the value in pure pyridine after fifty per cent of the alcohol is replaced by the pyridine. In the methyl alcohol-pyridine series the temperature coefficients increase rapidly to a maximum value in the fifty per cent mixture, then decrease slowly to the value in pure pyridine as the proportion of alcohol is diminished. The same relations obtain for binary mixtures of pyridine and ethyl alcohol, except that the maximum occurs in the presence of a smaller proportion of pyridine.

The heats of ionization are given in Table XIV. They were calculated by substituting the mean temperature coefficients and the electrode potentials for the 0.1 N solutions in equation (5). The heat of ionization in pyridine is very low. In any series of solvent mixtures, the heats of ionization decrease the most rapidly upon the first addition of pyridine to the second solvent, and then more slowly as the per cent of pyri-

[20] Loc. cit.

dine is increased. The heats of ionization decrease with increase of pyridine relatively more rapidly in each of the alcoholic-pyridine mixtures than in the water-pyridine mixtures.

In the last column of Table XIV are given a few dielectric constants[21]. It will be observed that in this respect also, the first addition of pyridine to the other solvent produces relatively the greatest change. Are then, the electrode potentials and heats of ionization functions of the dielectric constants?

The solution pressure of silver in contact with pyridine solutions of silver nitrate is found to be much higher than when in contact with aqueous or alcoholic solutions. These calculations were made by substituting in (6) the electrode potentials obtained for the 0.1 N solutions in each of the pure solvents, and the values of $\propto$ calculated from the following values of the equivalent conductivities: Water, $\lambda_{10}=99.46$[22] and $\lambda\infty=128.54$[23]. Methyl alcohol, $\lambda_{10}=38.575$[22] and $\lambda\infty=98.0$. Ethyl alcohol $\lambda_{10}=13.215$[22] and $\lambda\infty=35.6$[23]. Pyridine, $\lambda_{10}=27.585$[22] and $\lambda\infty=71.$[22]

The solution pressures in water and the alcohols are in good agreement with those calculated by Farr. The values calculated for water also are very close to the values 2.3x10-17, given by Neumann[24]. Assuming from conductivity data that silver nitrate is one-fourth as highly ionized in pyridine as it is in aqueous solutions, Kahlenberg calculated the solution pressure of silver in pyridine to be 3.4x10-10, a value very close to the one herein reported.

SUMMARY.

The electromotive forces of concentration cells containing solutions of silver nitrate in the pure solvents: water, methyl alcohol, ethyl alcohol, pyridine, and in the binary mixtures of pyridine with each of the other solvents have been determined at 0° and 25°. It has been shown that the Nernst equation cannot be applied to solutions of silver nitrate in pyridine, possibly because of a change in the solution pressure of the metal with the concentration of the salt or because of the association and subsequent complex ionization of silver nitrate in pyridine solutions. The equivalent conductance is not a measure of the concentration of the silver ions.

[21]Determined by Mr. Richard Beeson.
[22]This laboratory.
[23]Kohlrausch, Sitzungsber, Berl. Akad., 26, 570, 1902.
[24]Zeit. physik. Chem., 14, 193, 1894.

The electrode potentials have been determined for the same solvents at both temperatures. They are much higher in water, methyl alcohol and ethyl alcohol than in pyridine. In all solvents they are highest in the most concentrated solution, decreasing rapidly with the first dilutions and then almost linearly with further dilution. The electrode potentials in the binary mixture of pyridine with each of the other solvents decrease very rapidly with the first addition of pyridine. With further increase in the per cent of pyridine the values decrease gradually to that in pure pyridine. For the water pyridine series, beginning with twenty-five per cent pyridine, the decrease in the value of the electrode potential is linear with the per cent of pyridine.

The average temperature coefficients of electrode potentials have been calculated for each of the pure solvents and their binary mixtures. All are found to be positive except those in the dilute solutions in pure water. In water-pyridine mixtures the temperature coefficients increase continuously to the value in pyridine. In both alcoholic mixtures with pyridine they go through maximum values.

The heats of ionization of silver in the pure solvents and their binary mixtures are found to be much higher in water, methyl alcohol and ethyl alcohol than in pyridine. As the per cent of pyridine is increased in its mixtures with each of the other solvents, the heat of ionization decreases at first very rapidly and then more slowly to its value in pure pyridine.

The solution pressure of silver nitrate has been calculated for each of the pure solvents. It is much higher in pyridine than in either of the two alcohols or water.

Physical Chemistry Laboratory,
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AN OLD ROMAN COIN IN DAKOTA.

DAVID H. BOOT.

In 1910 the writer was at work in Lincoln county, South Dakota, and had his attention called one morning to a curious piece of metal that had just been dug up by one of his neighbors. The find was apparently an old coin, but no one in that region could identify it. It was sent to the Smithsonian Institution and there identified as a coin of Septimius Severus, Emperor of Rome, A. D. 193 to 211. Some account of this Roman Emperor will be of interest in this connection. He was the only negro that ever ruled the world. In 193 he was commander of the Roman army on the Danube, engaged in holding off the armies of the barbarians. He was an Ethiopian who had risen from the ranks by his great energy and force of character. The Emperor Pertinax having been murdered in Rome,

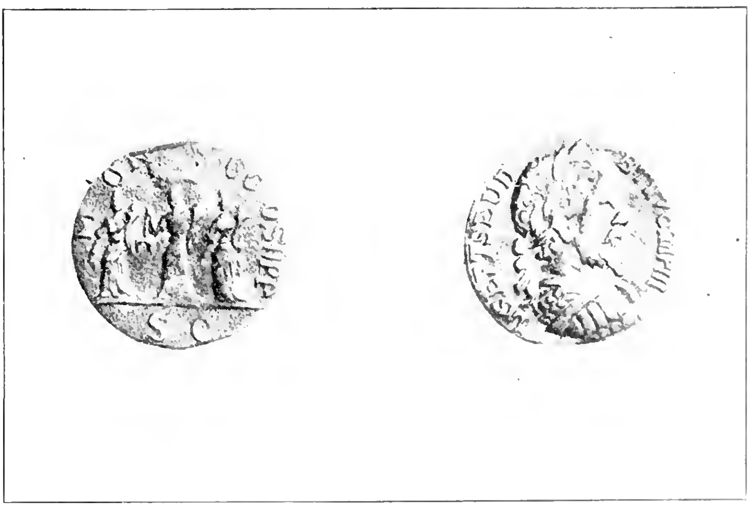


FIG. 3—Coin of Septimius Severus found in South Dakota.

the praetorian guard auctioned off the empire to the highest bidder and it was sold to Didius Julianus for a price equivalent to $12,000,000 of our money. At this time there were three armies in the field protecting the empire, one on the Euphrates, one on the Rhine and one on the Danube. When the soldiers heard of the disgraceful transaction at home they rose in revolt and at once set out for the capital. Septimius Severus had the shortest distance to go and reached Rome first. The praetorians did not even attempt to defend their emperor who was put to death along with forty senators, and the army proclaimed Severus emperor. He knew that as soon as the excitement of the moment had passed, the people would not tolerate a negro ruler so he very wisely committed the management of affairs at the capital to the prefect of the new praetorian guard and returned to the frontier where he spent a long and prosperous reign, only returning two or three times and then for a few days only. He finally died in Britain at York.

The cuts (figure 3) show front and back views of the coin found in Dakota. Conjecture is useless as to how it came there, for the first white man to cross Dakota is supposed to have been the French explorer Venendre, but the coin was more than 1400 years old when Venendre was born. French Jesuit priests later worked among the Indians of Dakota, but it would be difficult to arrive at any reasonable hypothesis involving their connection with it.

DEPARTMENT OF BOTANY,
STATE UNIVERSITY.

A NOTE REGARDING THE PRESENT STATUS OF THE IOWAN DRIFT PROBLEM.

GEORGE F. KAY.

Among the many persons who, by their publications, have made known to the world the Pleistocene history of Iowa, no one has had a greater part than Doctor Calvin, who spent his life endeavoring to interpret the geological phenomena of the state. For many years, but chiefly from about 1895 until his death in 1911, important papers were written by him in the reports of the Iowa Geological Survey, of which he was Director, and in other channels of publication. None of these publications are of greater interest than those which describe the characteristics, relationships, and age of the Iowan drift. It was he who, after he had done detailed work on the Pleistocene of the northeastern and north-central parts of Iowa, became convinced that in this part of the state the evidence indicated that the ice had invaded the region not twice only, as had been held by earlier workers in this field, but three times. It was he who gave to the uppermost of these drift sheets the name "Iowan," and presented arguments in favor of recognizing the Iowan as a distinct epoch in the Pleistocene.

For a number of years the conclusions of Doctor Calvin were accepted, but a few years before his death in 1911 some Pleistocene geologists, particularly Mr. Frank Leverett of the United States Geological Survey, raised the question whether or not there was sufficient evidence to justify the recognition of the Iowan as a drift sheet separate from the Kansan. In defense of his interpretations Doctor Calvin prepared a paper entitled "The Iowan Drift," which he read at the Pittsburgh meeting of the Geological Society of America, in December, 1910, and which was published after his death in the Journal of Geology, volume XIX, No. 7, October-November, 1911.

Since the death of Doctor Calvin, a co-operative study of the Iowan problem has been made, especially during the field seasons of 1914 and 1915, by Dr. W. C. Alden, Chief of the Pleistocene Section of the United States Geological Survey, and Dr.

M. M. Leighton of the Iowa Geological Survey. Their investigations have confirmed the contention of Doctor Calvin that in northeastern and north-central Iowa there is an Iowan drift. In September, 1915, after the completion of the field work of Alden and Leighton, a conference was held in the Iowan area, in which conference Dr. W. C. Alden, Mr. Frank Leverett, Dr. R. D. Salisbury, and the writer participated. After a critical study and discussion of the main lines of evidence in the field, agreement was reached by all that there is a post-Kansan drift to which the name "Iowan" was given by Calvin.

A report of the investigation of Doctor Alden and Doctor Leighton is now being prepared for publication by the Iowa Geological Survey.

Much of the evidence in connection with the Iowan is very elusive, and the fact that Doctor Calvin, who was regarded for many years not as a Pleistocene geologist but as a paleontologist, correctly interpreted the evidence indicates his keen powers of observation and his ability to discriminate evidence which one geologist has said "defies the experts."

DEPARTMENT OF GEOLOGY,
STATE UNIVERSITY.

CONTRIBUTIONS TO THE GEOLOGY OF SOUTHWESTERN IOWA.

GEO. L. SMITH.

During the last year work on the geology of southwestern Iowa has been continued. The different outcrops in the vicinity of Stennett in Montgomery county have been visited, and important information obtained of the stratigraphy and paleonology of the Stennett limestones and the Braddyville and Platte shales. In Fremont county the exposures at Hamburg, McKissicks Grove, Mill creek, as well as those from Opossum creek north to Thurman have again been examined, in hopes to definitely locate the break that takes place in the strata between Thurman and the Wilson section.

The unusual and excessive rainfall of the last summer made the field work disagreeable by the abundance of mud and high water. Erosion was many times greater than in any previous year. In several places overwash and slumping completely covered outcropping strata, while in other places the creek beds were swept bare and clean by high water, affording details of sections not before observed. Erosion has been especially active in the head of ravines in the loess of the Missouri river bluffs. At McKissicks Grove this has exposed about thirty feet of strata higher than those already known.

In tracing the different limestone ledges southward, there is found a marked change in the lithology of the horizon; the upper limestone at Nebraska City and Hamburg grades into sandstone in the state of Missouri, within twenty miles of the Iowa state line. Even at McKissicks Grove this limestone becomes very arenaceous, and at the most southern outcrop it might be termed a calcareous sandstone. The limestone bottom rock of the Nodaway coal at Carbon in places is five feet thick, southward at New Market it thins to eight inches, at Clarinda it is only a disconnected layer of nodules, and at Coin it is absent. One of the thin limestone ledges less than two feet thick at the Wilson section increases in thickness to twelve feet in less than a mile to the north. This shows the necessity of caution in correlations, and that all the associated strata must be taken into consideration in the identification of any horizon. Nearly all the available limestone on Tarkio creek is exhausted; no quarrying has been done lately, and in recent years no outcrop where a satisfactory section could be obtained was known. At Snow Hill, one mile north of Coin, recent erosion has exposed the following section. It is given as it is the only good outcrop at present on Tarkio creek.

SECTION ON TARKIO CREEK ONE MILE NORTH OF COIN.

		FEET.
9.	Shale, yellow passing down into blue..........	9
8.	Limestone, gray weathered yellow, Fusulina....	1
7.	Shale, gray, calcareous.........................	3
6.	Limestone, blue, weathered brown.............	2
5.	Sandstone, brown, friable.....................	1
4.	Shale, gray, weathered........................	6
3.	Limestone, gray...............................	1
2.	Shale, red.....................................	3
1.	Shale, gray, weathered........................	2
	Total	28

The upper eight inches of number six usually parts from the rest of the ledge, and in some localities this parting becomes a shale two feet thick.

About two hundred yards east of this outcrop near the Chicago, Burlington and Quincy railroad a core drill hole gives the following record of the City Bluffs shale. The drilling commences immediately beneath the Tarkio limestones exposed in outcrop at the old mill site.

SECTION OF CORE DRILLING ON RAILROAD NORTHEAST OF COIN.

		FEET	INCHES
21.	Light shale	16	8
20.	Gray shale...........................	11	4
19.	Gray limestone, impure, shaly..........	9	6
18.	Gray shale...........................	32	2
17.	Limestone, impure, shaly...............	6	
16.	Calcareous shale.......................	2	
15.	Light shale............................	3	8
14.	Black shale............................	2	
13.	Coal, Elmo.............................		6

		FEET	INCHES
12.	Light shale	3	
11.	Black shale	2	8
10.	Gray limestone, impure, shaly	3	4
9.	Gray shale	8	
8.	Limestone, impure, shaly	2	
7.	Green shale	16	9
6.	Gray shale	37	3
5.	Gray limestone	1	2
4.	Gray shale	44	3
3.	Caprock limestone	4	10
2.	Black shale	4	
1.	Coal, Nodaway	1	6
	Total	212	7

Records obtained of two core drill holes and two coal mine shafts within one mile of Coin show no constant horizon that can be correlated above the Nodaway coal in the City Bluffs shale.

Recent grading at Hamburg on the street north of the school house has exposed an excellent section. The bluff at this place reaches a height of about one hundred and fifty feet above the river flood lands, with the slope of the west face reaching nearly 45 degrees. The east slope is somewhat less. The crest is wide enough only for a narrow footpath. The surface of the shale bed rock closely follows the contour of the bluff, and at the contact of the shale and loess composing the upper part of the bluff, does not show any traces of weathering previous to the deposition of the loess.

The Iowa Geological Survey has published several sections of the strata in this bluff, only one of which is correct, that of J. A. Udden, in Vol. XIII, Iowa Geological Survey. At the time of the visit of Dr. Calvin and the writer the limestone and lower sandstone layers were concealed by debris and were not seen.

SECTION AT HAMBURG BLUFF.

		FEET	INCHES
6.	Sandstone, yellow, coarse grained, the grains composed of subangular fragments of quartz		3
5.	Shale, blue, weathered gray, contains concretions of pyrite	15	
4.	Limestone, dark gray, arenaceous, cut by vertical joints, brecciated, occasionally contains spheroidal lumps of dark		

		FEET	INCHES
	color. Some of the lumps consist of an external shell with an included structureless nucleus		9
3.	Shale, blue, arenaceous	5	
2.	Sandstone, blue, indurated, micaceous, and ripple marked	2	
1.	Shale, arenaceous	1	
	Total	24	

The limestone near the reservoir at the foot of the bluff was the foundation wall of a building that had been removed.

During the past summer slumping has covered some of the lower strata at McKissisks Grove; however, active erosion at the head of rävines has revealed details of strata not before observed. The outcrops at this locality are seen successively by following an unnamed creek to the forks, then the east branch about one-fourth mile; on the south branch are several excellent exposures within a distance of one-half mile. All these outcrops are easily fitted with each other.

COMPOSITE SECTION AT McKISSICKS GROVE.

		FEET	INCHES
19.	Shale, blue	12	
18.	Shale, gray, weathered	8	
17.	Limestone, very dark gray, arenaceous, many spheroidal lumps, in places brecciated	1	
16.	Limestone, blue, very arenaceous, might be termed a calcareous sandstone	1	
15.	Shale, arenaceous, micaceous	3	
14.	Sandstone, blue, weathering yellow	6	
13.	Shale, arenaceous, micaceous	2	6
12.	Sandstone, blue, weathering yellow	1	
11.	Shale, gray	9	
10.	Limestone, dark gray, fossiliferous, in two layers	3	
9.	Coal, Nyman	1	
8.	Shale, yellow and blue	31	
7.	Limestone, gray, fossiliferous		6
6.	Shale, dark gray	3	6
5.	Limestone, very dark gray		6
4.	Shale, blue weathering to yellow	8	
3.	Limestone, weathered brown. In two or three layers. Tarkio	4	
2.	Shale, gray, weathered	12	
1.	Limestone, dark gray	1	
	Total	110	

The twenty feet of shale, with the associated limestone bands, above the Tarkio limestone are highly fossiliferous. Two miles northeast of McKissicks Grove, about one-half the distance to the Mill creek outcrop, the Nyman coal has been prospected and found to have a thickness of one foot. The Mill creek outcrop can be correlated easily with that of McKissicks Grove. In passing north and east the upper limestone becomes less arenaceous and more fossiliferous.

SECTION ON MILL CREEK TWO MILES SOUTH OF RIVERTON.

		FEET
6.	Shale, gray, weathered	10
5.	Limestone in five layers with shale partings. The upper layer six inches thick is an indurated and white limestone composed of fragments of shells and crinoid plates arranged in a horizontal position. The two lower layers ten and four inches thick are a very dark gray limestone. They contain numerous round lumps of calcareous matter one-fourth inch in diameter	3
4.	Shale, calcareous, weathered yellow	3
3.	Shale, blue, arenaceous, contains several thin bands of sandstone, not well exposed	9
2.	Sandstone, blue, fine-grained, micaceous, indurated	2
1.	Shale, blue	8
	Total	35

On the bluff road north of Opossum creek to Thurman several outcrops of the same ledge of limestone and sandstone can be seen.

COMPOSITE SECTION SOUTH OF THURMAN.

		FEET	INCHES
5.	Sandstone, blue, fine texture		6
4.	Shale, gray	10	
3.	Limestone, dark gray, cut by vertical joints into large blocks, and containing numerous spheroidal calcareous lumps about one-fourth inch in diameter	3	

		FEET	INCHES
2.	Shale, gray, weathered	2	
1.	Sandstone, light blue, indurated, of fine texture, in straight layers below, and ripple marked above	3	
	Total	18	6

Lower strata are found in a coal shaft near one of the outcrops.

RECORD OF BAYLORS SHAFT SOUTH OF THURMAN.

		FEET	INCHES
6.	Blue limestone	3	
5.	Sandstone	5	
4.	Shale	20	
3.	Limestone		6
2.	Coal, Nyman	1	2
1.	Shale and sandstone		
	Total	29	8

What is thought to be the same limestone and sandstone is seen on the wagon road about one mile north of Thurman. The Nyman coal outcrops in the banks of Plum creek one-fourth mile east of the village.

A feature unusual in Iowa geology takes place between the north outcrop and the Wilson section about one mile distant. There is a break in the strata upwards of three hundred feet, and as a result the Forbes limestone and Nyman coal each have the same elevation above the flood land of the Missouri river. The sandstone beneath the main limestone at the Wilson section is not the same as that near Thurman; the latter is blue, indurated, ripple marked, and three feet thick, while the former is yellow, friable, micaceous, and eight feet thick in the old quarry east of Haynies. The texture and contained spheroidal lumps in the limestone at Thurman, Hamburg, McKissicks Grove, and Mill creek are the same at each place. As this limestone becomes arenaceous at these southern localities it loses its fossils, and farther south in the state of Missouri grades into sandstone and cannot be recognized.

The possibility that the coal at Baylors shaft is the Elmo coal has been considered. These two localities have been personally visited, and compared, but as a result the conclusion arrived at is decidedly against such correlation.

Whether the break south of the Wilson section is a fault or an abrupt monocline to the south cannot be definitely decided, at the present time, owing to the heavy covering of loess in the bluffs; at any rate there is no considerable dip in strata less than a mile apart.

Twenty years ago the quarrying industry was in a flourishing condition at Stennett. Many large quarries were in operation, affording excellent exposures of the different strata. In recent years this industry is practically abandoned, and owing to overwash and slumping a connected section can not be found. Many of the old quarries are completely covered, and not a single undisturbed ledge is visible.

On Pilot creek, one-fourth mile north of Stennett, at the site of the abandoned Wayne Stennett quarry, is the best and most extensive section seen in this vicinity.

SECTION AT THE OLD WAYNE STENNETT QUARRY.

		FEET
15.	Limestone, gray, two layers	2
14.	Shale, black	3
13.	Shale, gray, calcareous	5
12.	Limestone, gray, one layer	2
11.	Shale, gray, calcareous	2
10.	Limestone, gray, one layer	1½
9.	Shale, buff and gray	3½
8.	Limestone, brown, cherty, impure	1
7.	Limestone, gray, cherty	2½
6.	Limestone, blue	1
5.	Limestone, buff	1
4.	Limestone, blue	1
3.	Limestone, buff, cherty	2
2.	Limestone, blue	3
1.	Limestone, gray	4
	Total	34½

The limestones below the shale member number 9 are the upper layers of the Forbes limestone. In the bed of the creek are several additional feet of limestone belonging to this formation. The upper part of the section is the base portion of the Braddyville beds.

On the Millner farm, about one hundred rods above the bridges on the creek, thirty feet of Nishnabotna sandstone rests upon the black shale number 14. In the year 1900 Doctor Calvin and the writer found specimens of *Anomphalus rotulus* in the shale bed number 9. The dominant fauna of this horizon is *Ambocoelia planoconvexa*, both valves, and *Pugnax uta*.

One mile north of Stennett on the west side of the river, about one hundred yards above the old mill site, road grading has exposed twelve feet of Nishnabotna sandstone, the base of which must reach nearly down to the Platte shales. For a distance of one-half mile south of the mill site in the bluffs on the west side of the river, is the location of the old extensive quarries of the past; at present they are so obscured by slumping no section can be obtained.

Directly west of Stennett recent road grading has uncovered the contact of the Platte and Forbes formations at the foot of the bluffs.

SECTION ONE-HALF MILE WEST OF STENNETT.

		FEET	INCHES
7.	Limestone, in thin layers badly shattered	5	
6.	Limestone, gray, cherty	1	6
5.	Limestone, shaly	2	
4.	Shale, gray	1	
3.	Shale, black, carbonaceous	1	6
2.	Shale, gray, calcareous	2	
1.	Shale, blue	4	
	Total	17	

Several thin bands in the shale number 2 are almost entirely composed of specimens of *Chonetes granulifer* and *Squamularia perplexa*. The strata dip at the rate of twenty-five feet to the mile, north of east from the outcrops west of the river to Pilot creek. A number of the gray limestone layers carry many nodular masses of black chert, and in places are oölitic in texture. Of all the limestones in the Carboniferous of southwestern Iowa the Stennett limestones deserve the name of Fusulina limestone. In past years when the quarries were in active operation, in the debris, at the foot of the limestone ledges Fusulina could be found in millions. There seems to be a varietal or even a specific difference in the Fusulina at Stennett and those at McKissicks Grove; the former are large and globular, the latter long and curved forms.

Two miles southwest of Stennett on the Red Oak wagon road and one-fourth mile from a coal prospect tunnel the following is seen in outcrop:

		Feet
2.	Sandstone, yellow, friable	5½
1.	Limestone, gray	3
		8½

The sandstone number two is the same as that exposed in the quarries east of Haynies, and immediately underlies the blue shale, number one in the section west of Stennett.

COMPOSITE SECTION OF DIFFERENT OUTCROPS IN THE VICINITY OF STENNETT.

	Feet
Limestone, gray, two layers	2
Shale, black	3
Shale, gray, calcareous	5
Limestone, gray, one layer	2
Shale, gray, calcareous	2
Limestone, gray, one layer	1½
Shale, buff and gray	3½
Limestone, variable	17
Shale, gray	1
Shale, black, carbonaceous	1½
Shale, gray, calcareous	2
Shale, blue	4
Sandstone, yellow, friable	5½
Limestone, gray	3
	53

The late Doctor Calvin maintained that the strata in southwestern Iowa below the Nyman coal were abyssal sea deposits; those above this coal mostly marginal, as shown by spheroidal lumps in the limestones and ripple marked sandstones; also that the Nodaway coal was formed in a marine swamp, as the bottom and roof shales of this coal have an abundant marine fauna. A careful search has been made for fossils of the Lingula group, as these are good evidence of shallow water deposits, with the result that only a few doubtful forms have been discovered. The upper limestone above the cap rock of the Nyman coal not being a constant horizon it is thought best to leave it unnamed, as it can not be identified in the state of Missouri, within a few miles of the Iowa state line.

Collections of fossils have been made at Stennett, near Thurman, Hamburg, McKissicks Grove, and Mill creek, south of Riverton. The lower twenty feet of shales above the Tarkio limestone and the Nyman coal cap rock at McKissicks Grove are highly fossiliferous, while the upper arenaceous limestone is sparingly so. It is thought advisable to list the fauna of the upper limestone at Thurman and Mill creek separately.

THURMAN FAUNA.

FORAMINIFERA—
- Fusulina secalica.

ANTHOZOA—
- Lophophyllum profundum.

CRINOIDEA—
- Ceriocrinus hemisphericus.

BRYOZOA—
- Fenestella perelegans.
- Fistulipora nodulifera.
- Rhombopora lepidodendroides.

BRACHIOPODA—
- Ambocoelia planoconvexa.
- Chonetes geinitzianus.
- Chonetes granulifer.
- Hustedia mormoni.
- Marginifera wabashensis.
- Productus cora.
- Productus semireticulatus.
- Pugnax uta.
- Seminula argentea.
- Spirifer cameratus.

PELECYPODA—
- Allorisma terminale.
- Aviculopecten occidentalis.
- Edmondia nebrascensis.
- Myalina swallovi.

GASTROPODA—
- Euphemus carbonarius.

MILL CREEK FAUNA.

FORAMINIFERA—
- Fusulina secalica.

BRACHIOPODA—
- Chonetes geinitzianus.
- Chonetes granulifer.
- Spirifer cameratus.

PELECYPODA—
- Aviculopecten providencesis.
- Myalina swallovi.

GASTROPODA—
- Bucanopsis marcouanus.

It is a surprise that *Aviculopecten providencesis* should be found so high in the Carboniferous. The identification can not be mistaken, for, as stated by Beede, it is easily separated from the other Carboniferous species by its large size and fasciculation of the striae.

McKISSICKS GROVE FAUNA.

LOWE SHALE FAUNA.

FORAMINIFERA—
- Fusulina secalica.

ANTHOZOA—
- Lophophyllum profundum.

CRINOIDEA—
- Ceriocrinus hemisphericus.

BRYOZOA—
- Fistulipora nodulifera.
- Rhombopora lepidodendroides.

BRACHIOPODA—
- Ambocoelia planoconvexa.
- Chonetes geinitzianus.
- Chonetes granulifer.
- Dielasma bovidens.
- Enteletes hemiplicata.
- Hustedia mormoni.

Meekella striatocostata.
Orthothetes crassa.
Productus cora.
Productus costatus.
Productus nebrascensis.
Productus punctatus.
Productus semireticulatus.
Pugnax uta.
Rhipidomella pecosi.
Seminula argentea.
Spirifer cameratus.

PELECYPODA—
Aviculopecten occidentalis.
Aviculopecten whitei.
Edmondia nebrascensis.
Entolium aviculatum.
Leda bellistriata.
Myalina perattenuata.
Myalina subquadrata.
Myalina swallovi.
Parallelodon tenuistriatus.
Schizodus wheeleri.

GASTROPODA—
Aclisina stevensana.
Bucanopsis marcouana.
Bucanopsis montfortiana.
Euomphalus catilloides.
Euphemus carbonarius.
Phanerotrema grayvillensis.

NYMAN COAL CAP ROCK FAUNA.

FORAMINIFERA—
Fusulina secalica.

BRYOZOA—
Rhombopora lepidodendroides.

BRACHIOPODA—
Ambocoelia planoconvexa.
Chonetes granulifer.
Enteletes hemiplicata.
Marginifera longispina.
Orthothetes crassa.
Productus costatus.
Productus semireticulatus.
Pugnax uta.
Seminula argentea.
Spirifer cameratus.

PELECYPODA—
Myalina subquadrata.

GASTROPODA—
Euomphalus catilloides.
Phanerotrema grayvillensis.

TRILOBITA—
Griffithides scitula.

UPPER LIMESTONE FAUNA.

BRYOZOA—
Rhombopora lepidodendroides.

BRACHIOPODA—
Ambocoelia planoconvexa.
Pugnax uta.

PELECYPODA—
Myalina swallovi.

As many of the fossils collected at Stennett were found in the debris of old quarries it is impossible to discriminate closely between horizons. Those found in situ in the Braddyville and Platte formations are listed separately.

The species of Orthothetes differs from *Orthothetes crassa* found in the shales associated with the Nodaway coal, as it is much larger, with the dorsal valve more convex. It is doubtfully identified as *Orthothetes robusta.*

STENNETT FAUNA.

Braddyville Formation.

Foraminifera—
- Fusulina secalica.

Brachiopoda—
- Ambocoelia planoconvexa.
- Dielasma bovidens.
- Hustedia mormoni.
- Orthothetes robusta.
- Productus cora.
- Pugnax uta.
- Seminula argentea.
- Spirifer cameratus.

Gastropoda—
- Anomphalus rotulus.

Platte Formation.

Anthozoa—
- Lophophyllum profundum.

Brachiopoda—
- Chonetes granulifer.
- Marginifera longispina.
- Productus cora.
- Productus symmetricus.
- Seminula argentea.
- Squamularia perplexa.

Forbes Formation, Main Ledge, and in Debris.

Foraminifera—
- Fusulina secalica.

Anthozoa—
- Lophophyllum profundum.

Crinoidea—
- Ceriocrinus hemisphericus.
- Eupachycrinus tuberculatus.
- Hydreionocrinus mucrospinus.

Echinoidea—
- Archaeocidaris agassizi.
- Archaeocidaris dininni.
- Archaeocidaris hallanus.
- Archaeocidaris triserrata.

Bryozoa—
- Fenestella tenax.
- Fistulipora nodulifera.
- Polypora submarginata.
- Rhombopora lepidodendroides.
- Septopora biserialis.

Brachiopoda—
- Ambocoelia planoconvexa.
- Chonetes granulifer.
- Chonetes verneuilana.
- Dielasma bovidens.
- Enteletes hemiplicata.
- Hustedia mormoni.
- Marginifera longispina.
- Meekella striatocostata.
- Productus cora.
- Productus costatus.
- Productus nebrascensis.
- Productus semireticulatus.
- Pugnax uta.
- Rhipidomella pecosi.
- Seminula argentea.
- Spirifer cameratus.
- Spiriferina kentuckiensis.
- Squamularia perplexa.

Pelecypoda—
- Allorisma terminale.
- Chaenomya minnehaha.
- Myalina swallovi.
- Schizodus wheeleri.

Gastropoda—
- Bellerophon percarinatus.
- Euomphalus catilloides.
- Euphemus carbonarius.
- Platyceras parvum.
- Soleniscus intercalaris.

Cephalopoda—
- Orthoceras knoxense.

The writer in the past has used the nomenclature of Grabau and Shimer in "North American Index Fossils." However, certain changes should be made, as some of the specific names used are synonyms.

Chonetes geinitzianus, Waagen, for *Chonetes glabra; Lophophyllum distorta,* Worthen, for *Lophophyllum west; Marginifera wabashensis,* Norwood and Pratten, for *Marginifera muricatus; Orthoceras knoxense*, McChesney, for *Orthoceras rushense* as stated by Meek in "Final Report on Nebraska;" *Soleniscus paludinaeformis* is probably equivalent to *Soleniscus intercalaris,* Meek and Worthen, although this species has a strong fold on the columella which seems to be absent in Meek's description and figure. The substitution of Echinocrinus for Archaeocidaris is a biological misnomer, and the term is not used. There is no marked change in the brachiopod species in the whole series of strata; *Productus pertenuis* has not been found below the Nodaway coal or *Squamularia perplexa* above the Platte shales. The dominant feature of the Stennett limestone is the numerous species of Archaeocidaris. No limestone in southwestern Iowa has such an abundance of Fusulina. The dominant feature in the lower limestone fauna on the Nodaway is *Spirifer cameratus.*

Mr. Hy Clement of McKissicks Grove conducted the writer to outcrops a stranger would never discover. Studies of the Structural and Economic Geology of this part of Iowa are in progress.

BIBLIOGRAPHY.

Geo. H. Girty, Fauna of the Wewoka Formation: Bull. U. S. Geol. Survey, No. 544, 1915.

Hinds and Greene, Stratigraphy of the Pennsylvanian of Missouri: Missouri Geol. Survey, Vol. 13, 1915.

Chas. R. Keyes, Synopsis of American Paleozoic echinoids: Proc. Iowa Acad. Science, Vol. 2, 1895. Foundation of exact Geologic Correlation: Proc. Iowa Acad. Science, Vol. 22, 1915.

Samuel Calvin, Geology of Page County: Iowa Geol. Survey, Vol. 11, 1900.

Pirsson and Schuchert, Text Book of Geology: Intraformational conglomerates. 1915.

C. D. Walcott, Paleozoic intraformational conglomerates: Geological Society of America. Bull. Vol. 5, 1893.

RECORDS OF OSCILLATIONS IN LAKE LEVEL AND RECORDS OF LAKE TEMPERATURE, AND OF METEOROLOGY, SECURED AT THE MACBRIDE LAKESIDE LABORATORY, LAKE OKOBOJI, IOWA, JULY, 1915.

JOHN L. TILTON.

At the Macbride Lakeside Laboratory, Milford. Iowa, the writer began a series of observations last summer (1915) for his own information to ascertain what the fluctuations were in the level of the lake, and to determine the relative value of the causes that operated to produce those fluctuations. It soon became evident that the records sought were desired also by teachers in other departments because of the bearing of such data on life zones and conditions in the lake. Since then the government has called for all data available on evaporation in Iowa. The data are therefore here presented that they may be of immediate use and on file for future reference.

To detect the oscillations in the level of the lake it first became necessary to devise a piece of apparatus for that purpose. A closed hollow cylinder two inches in diameter was placed as a float in a larger cylinder three inches in diameter, closed at the bottom. Through the sides of this outside tube a few nail-holes were punched to let in the water slowly so that the float inside of this tube would rise and fall gradually but not move perceptibly for small waves. This was placed in a vertical position in the water close to the boathouse where the water was about four feet deep. It was found that waves five or six feet from crest to crest and perhaps a foot from trough to crest would move the float about the twentieth of an inch. When a steamer made a landing the float would rise and fall about three-eights of an inch. To an upright rod fastened to the float a thin strip of brass was attached, on the end of which was a pen which traced all vertical movements on a cylinder that revolved once a week by clock work. The revolving cylinder, the pen and penholder, were parts of a thermograph which was thus made to serve present purposes.

As might be expected the tidal effect (estimated at .0016 inch) could not be detected at all in a direct reading device of this kind; but the conditions involved deserve attention. The distance from the laboratory to Arnold's Park (west to east) is

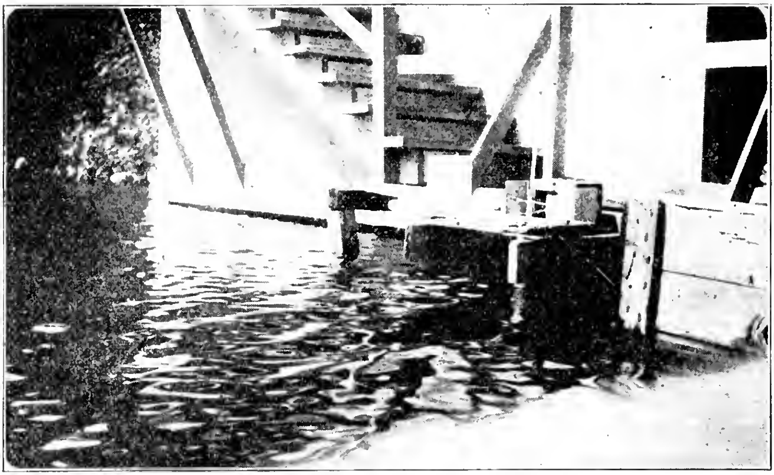


FIG. 4—The recorder of variations in the level of the lake.

two and three-fourths miles. From this line north to the head of the lake the distance is three and a half miles, approximately the same as the east and west stretch of water. When the east and west stretch alone is considered it should be low tide when the moon rises and high tide when the moon sets, with neutral effect when the moon is on the meridian. When the north and south stretch alone is considered it should be high tide when the moon is on the meridian, with neutral effect when the moon rises and when it sets. Thus even these minute differences almost exactly neutralize each other.

Oscillations due to changes in barometric pressure were also too minute to be detected by direct registration without magnification. One of several computations made to ascertain the magnitude of such oscillations resulted as follows: On June 30 the weather map gave a barometric pressure of .00041½ pounds per square inch at West Okoboji (at the north end of the lake) in excess of that at the laboratory, which pressure would be counterbalanced hydrostatically by a rise of .00095 inch in the level of the lake at the laboratory. This difference in barometric pressure was one of the most marked differences that occurred during the period of observation.

The inflow at the head of the lake, and the outflow over the dam were not gauged, but by inspection they were judged fairly to compensate each other.

The main changes in level were due to evaporation, to precipitation and to strong winds. For each continuous period of evaporation without strong wind there was a steady drop in the level of the lake of from .1 to .3 inch per day. A similar effect of evaporation was detected when from the height marked by the gauge the rise due to precipitation was subtracted. The records of evaporation and of precipitation were obtained from a glass battery jar about eight inches in diameter and eight inches high placed over the lake and about a foot above it.

The rise due to precipitation was very evident, at one time carrying the pointer above the cylinder. (The rise due to precipitation may be seen in the records for July 6, 11, 15, 19, 26 and 30. Apparently friction slightly interfered with the freedom of motion of the pen the first week.)

The total drainage area of the lakes West and East Okoboji estimated from the county map of the Iowa Geological Survey is fifty-five square miles; the area of the lake itself eight and four-tenths square miles. One inch of rainfall over the drainage area would raise the level of the lake 6.55 inches if all of the precipitation were to reach the lake. Evidently much of the precipitation would soak into the ground and later be evaporated without reaching the lake at all. Precipitation is generally unevenly distributed over the area in thunder storms, and the immediate effect on the level interfered with by the wind. In one instance precipitation of 1.2 inches at the point of observation was actually accompanied by a fall in the level of the lake at that point.

Rise and fall due to the wind was not so great as was expected, for the crests of the waves under strong wind pressure present a deceiving appearance. Apparently the differences in level due to the wind are quickly relieved by a general compensating movement in the lake. In general a strong wind from the southwest, west and northwest causes a slight fall in the level of the surface of the lake at the laboratory, while a strong northeast, east and southeast wind causes a corresponding rise in the surface at the laboratory. Effects of the wind in lowering the level of the lake at the laboratory may be seen in the record for June 29, July 1, 10, 11, 14, 16, 19, 20, 25. Effects of the wind in raising the level of the lake at the laboratory may be seen in the record for July 9, 12, 16 and 28. The effect of large waves superimposed on the effects of evaporation, precipitation and wind are to be noticed in the tracing for June 29, 30, July 7, 12-14, 15 (very pronounced), 19, 20, 21, 22, 24-25, 27-28.

THE TEMPERATURE OF THE LAKE.

Three series of observations of the temperature of the lake were obtained: one at the end of the pier at the laboratory

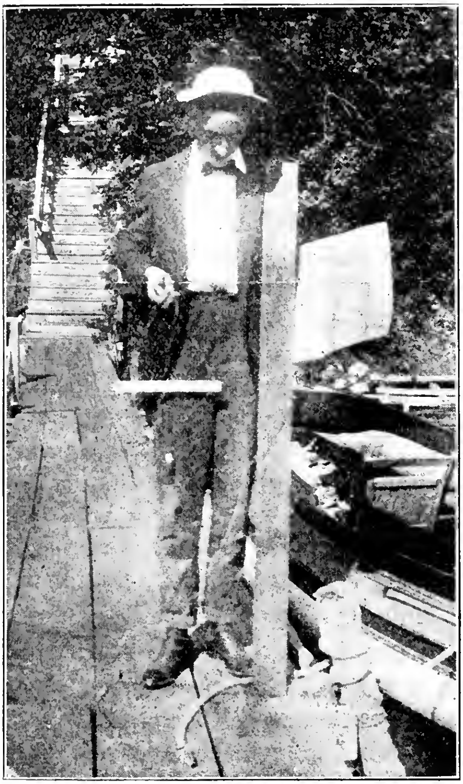
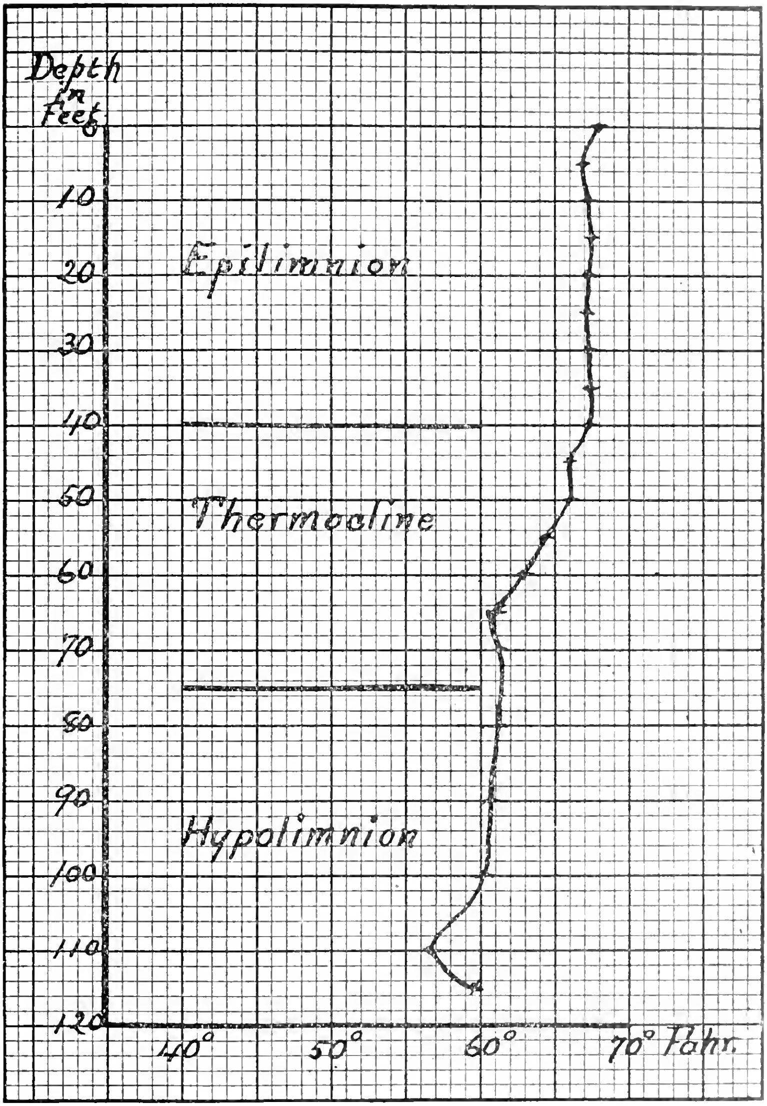


FIG. 5—Apparatus used to ascertain the temperature of the water at different depths.

where the water was six and a half feet deep; one, half way between the pier and the spit and hook at the entrance to the bay; and one close to the center of oscillation of the lake, as



Temperature curve for Lake Okoboji, August 5, 1915.

near as possible to the place where the record of depth when the lake was surveyed was 132 feet. The records of temperature were taken by a minimum thermometer kept in a horizontal position and weighted so as to sink readily.

The following are records of the temperature at the bottom of the lake near the center of oscillation July 13:

Depth Feet	Temperature Fahr. Degrees
85	59
135	56
124	55
115	59
124	59
115	58½

Series of temperatures obtained August 5, 1915:

Depth Feet.	Temperature Fahr. Degrees.	Depth Feet.	Temperature Fahr. Degrees.
0	68.0	50	66.0
5	67.0	55	64.2
10	67.1	60	62.9
15	67.3	65	60.5
20	67.1	70	61.3
25	67.1	80	61.1
30	67.1	90	60.7
35	67.3	100	60.0
40	67.4	110	56.5
45	66.0	115	59.8

At the end of the pier at the laboratory: at surface, 68.7°; at the bottom, 67.1° (six and a half feet deep).

Half way between the pier and the hook: at the surface, 68.3°; at a depth of 5 feet, 67°; at the bottom, depth 10 feet, 67°. The daily observations of the temperature of the water at the end of the pier are recorded with meteorological data in tables at the end of this paper.

The observations at the end of the pier give a surface temperature of the water that follows the curve of maximum temperatures of the air. The curve of maximum temperature varied with the amount of sunshine. The surface temperature of the water fluctuated between 64° Fahr. and 75° Fahr., often in the morning toward the latter part of the month being above the temperature of the air at the time, and also above the temperature of the air during stormy weather. A day of bright sunshine with little wind produced a rise of a degree or two in the temperature of the surface water. In the evening the difference in temperature between the surface at the end of the pier and the bottom at the same place (six and a half feet deep) was sometimes as much as two degrees, at one time after a day of bright sunshine with little wind amounting to five degrees (July 12). Even this large difference in temperature was nearly equalized by circulation during the night. A little wind was commonly enough to bring in and down the warm surface water of the lake, or to blow out and away the warm surface water, causing the colder water below the surface to rise. The morning observations often gave the same temperature at the surface as at the bottom at the end of the pier, and but three times (July 5, 14 and 30) giving a greater difference than one degree. These were days of bright sunshine and little wind.

The data for the temperature curve of the lake were obtained the fifth of August, as late as it was convenient to gather the data. Unfortunately the entire week preceding that date was characterized by clouds, strong wind and somewhat of rainfall, which condition accounts for the irregularity noticeable in the curve of temperature. Even in this irregularity the planes of demarcation of the three zones are pronounced. The area of the hypolimnion extends from near Terrace Park northward through the central portion of the lake to opposite the center of Omaha Beach. The thermocline extends over this area and a little to each side of it from Terrace Park to Omaha Beach and then extends northward to opposite Pikes Point. It is to be noted that within the epilimnion (where the water is forty feet or less in depth) is included the waters of all the bays of West Okoboji, all of Lower, Middle and Upper Gar Lakes, and all of East Okoboji for which data on depth are recorded. The volume of water of West Okoboji included in the epilimnion at the time of observation, which was very nearly the maximum for the year,* is computed as approximately 171,540,503 cubic yards. The volume in the thermocline, twenty-five feet thick, is approximately 72,709,309 cubic yards, and the volume in the hypolimnion approximately 38,713,961 cubic yards. The above figures are based on the soundings made in 1905 by the engineering students of Iowa State College.

*Edward A. Birge and Chancey Juday, "A Limnological Study of the Finger Lakes of New York," Bulletin of the Bureau of Fisheries, Vol. 32, 1912, Document No. 791, page 546.

THE METEOROLOGICAL DATA.

The month of July, 1915, is reported to have been an unusually cold and rainy month for that time of the year. The maximum temperature ranged between 70° and 87° Fahr., and the minimum from 44° to 70.5° Fahr. The relative humidity varied from 52 per cent to 100 per cent, was often close to 100 per cent and very often above 90 per cent. The details of the data are in the tables that follow, and are made use of in the analyses of the curves.

COMMENTS ON PLATES III AND IIIA.

On June 30 the barometric pressure at the north end of the lake in excess of that at the laboratory was sufficient to cause a rise of .00095 of an inch in the level of the lake at the laboratory. The preceding day there was no difference in the barometric pressure at these two extremes, but there was a gradual fall in the level of the lake, suggesting the need of a record of precipitation, evaporation, intake and outflow. Observations on precipitation and evaporation were begun July 5.

July 1 the level of the water fell quickly a quarter of an inch on change of wind from southeast to northwest.

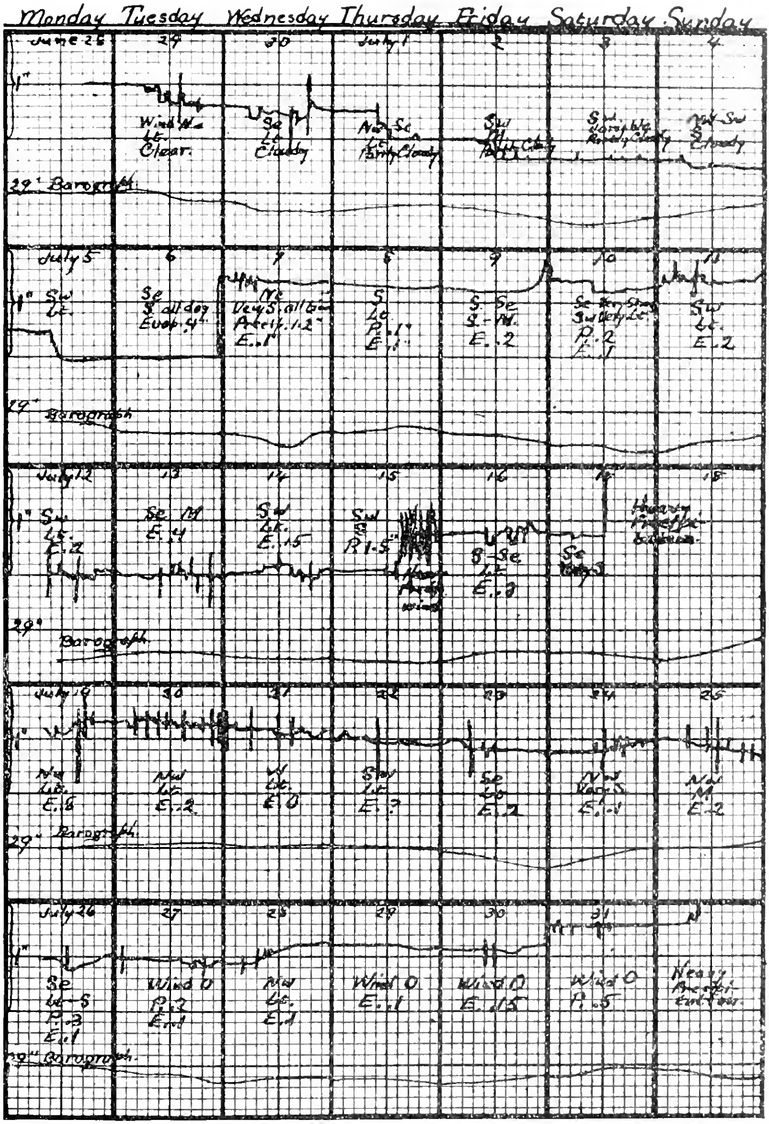
July 3 the excess of barometric pressure at the laboratory over that at north end of the lake should have caused a lowering of the water of .0021 of an inch at the laboratory and have maintained that difference that day and the next. To make such a variation evident the apparatus should magnify the movement at least thirty times, and preferably fifty.

July 5 a light southwest wind during the afternoon, aided somewhat by evaporation, sent the pointer below the bottom of the scale. July 7 the wind shifted to the northeast, and the water rose quickly one and one-half inches (from the bottom of the scale to that height), which level it maintained approximately for about three days.

July 7 the excess of barometric pressure at Arnold's Park over that at the laboratory would cause a rise of .015 of an inch.

July 8 the excess of barometric pressure at East Okoboji (north end of the lake) would cause a rise of .03 of an inch in the level of the water at the laboratory.

July 12-15. If allowance be made for evaporation the general course of the line is horizontal during a short period of clear weather with medium to light winds. There are, however, rythmic curves noticeable with a maximum variation of about one-fifteenth of an inch on the 12th, 13th and 14th, apparently due to variations in the wind; and also variations lasting from one to three hours amounting to 1-30 inch for which no suitable explanation is at hand. The long variations of ap-



Graphs of fluctuations in the level of the lake from June 28 to July 31, 1915. The heavy line gives the fluctuations and the light line the barometric pressure; other related data are included.

proximately half an inch are thought due to waves caused as a steamer made a landing and left, as these lines were made in the daytime and at hours when the steamer was due.

July 15. There was a strong southeast wind till the rain began to fall; then the wind shifted and blew hard from the southwest at about 3:30 P. M. The precipitation amounted to one and one-half inches, but the gauge recorded a rise of only half an inch, the difference being due apparently to the strong wind.

July 16. The pronounced rhythm is not due to the effects of the storm because the line is straight from midnight to daybreak and straight again Friday night. It is possible the rhythm is due to changing winds of which there is no exact record.

July 17. There was heavy precipitation and changing winds of which there is no record, excepting as the heavy precipitation raised the pen above the revolving cylinder of the gauge (1 and 5-16 in.) Apparently there was a fall of 3-32 inch at eleven o'clock A. M., just before the rain came.

July 19-25. The graph is characterized by a constant and almost uniform lowering of the level of the lake due to evaporation, equalized by a somewhat strong northwest wind on the 24th, when the line traced became almost horizontal. The remainder of the week the wind was light and the barometric gradient zero.

July 26. The rise was due to precipitation.

July 28. The marked rise of three-tenths of an inch was due to the wind which then began to blow from the northwest.

July 30. The rise was due to precipitation.

SUMMARY.

Tidal effects were almost zero, barometric effects too small to be detected without magnification, and intake and outflow about equal. Wind effects were noticeable, and when strong wind was not prolonged, were quickly compensated by movement in the lake. The wind directed the circulation in the lake. The division of the lake water in epilimnion, thermocline, and hypolimnion was pronounced, even after strong winds. Evaporation amounted to about two-tenths inch per twenty-four hours. Rainfall caused an immediate rise in the hydrograph.

TABLE OF METEOROLOGICAL AND LAKE DATA.

				7 A. M.					12 M.				7 P. M.				7 A. M.						7 P. M.					
	MAX.	MIN.	WIND	VEL.	DRY	WET	REL. HUM.	DEW PT.	DRY	WET	REL. HUM.	DEW PT.	DRY	WET	REL. HUM.	DEW PT.	T. TOP	T. BOTTOM	WIND	VELOC.	PREC.	EVAP.	T. TOP	T. BOTTOM	WIND	VELOC.	PREC.	EVAP.
June 22	78	----	Nw	M	----	----	----	----	----	----	----	----	68	59	59	53	----	----	----	----	----	----	66	----	----	----	----	----
23	77	56	Sw	----	----	----	----	----	66	65	95	64	72	66	73	63	63	----	----	----	----	----	----	----	----	----	----	----
24	71	58	Nw	Lt	61	59.5	89	59	66	63	85	61	66	63	85	61	63.5	----	----	----	----	----	67	65.5	----	----	----	----
25	78	58	Sw	Lt	66	62	80	60	----	----	----	----	75	67	66	63	65	----	----	----	----	----	70	66	----	----	----	----
26	87	64	Se-Sw	St	69	66	85	64	----	----	----	----	77	67	59	62	70	65	----	----	----	----	71	65	----	----	----	----
27	83	62	Se	M	----	----	----	----	79	71	67	67	77	72	78	70	----	----	----	----	----	----	71	65	----	----	----	----
28	78	65	Se	Lt	----	----	----	----	75	69	74	66	75	69	74	66	69	67	----	----	----	----	69	67	----	----	----	----
29	76	58	Nw	Lt	62	59	84	57	----	----	----	----	66	62	80	60	66	63	----	----	----	----	69	68	----	----	----	----
30	75	55	Se	Lt	58	56.5	89	56	74	64	58	58	68	64	81	62	68.5	68	----	----	----	----	73	69.5	----	----	----	----
July 1	83	63	Nw-Sw	St-Lt	65	61.5	59	59	82	69	52	62	68	63	76	60	71	69					71	69				
2	70	52	Sw	M	57	54	82	52	67.5	58.5	59	52	61	55	68	50	68	67	----	----	----	----	69	69	----	----	----	----
3	74	47	Sw	Var	49	48	93	47	70	59	52	51	60	55	73	51	67	66	----	----	----	----	67	66	----	----	----	----
4	74	44	Nw-Sw	St	58	53	72	49	65	58	66	53	62	55	64	50	65.5	65	Nw-Sw	St	----	----	66	66	----	----	----	----
5	71	45	Sw	Lt	60	56	78	53	70	60	56	53	67	59	62	54	61	62	Sw	Lt	----	----	66	66	----	----	----	----
6	78	57	Se	St	62	60	89	59	75	68	70	61	74	69	78	67	64.5	61.5	Se	St	----	.15	69	66.5	Se	St	----	.25
7	74	64	----	----	64	64	100	64	63	62	94	61	63	62.5	98	62	67	67	Ne	St	1.2	----	68	66.5	Ne	St	----	.1
8	71	58	----	----	62	60	89	59	67	62	76	59	68	64	81	62	65.5	65	0	0	----	.1	68.5	67.5	S	M	.1	----
9	70	58	----	----	65	63	90	62	66	64	90	63	66.5	65	97	66	66.5	66.5	S	St	----	.1	68	67	Se	M	----	.1
10	80	61	----	----	66.3	66.1	98	65	72	69	86	68	75	72	86	71	66.5	66.5	Se	V'ry St	.2	----	68	66.5	Sw	Lt	----	.1

TABLE OF METEOROLOGICAL AND LAKE DATA.—Continued.

				7 A. M.					12 M.				7 P. M.				7 A. M.						7 P. M.					
	MAX.	MIN.	WIND	VEL.	DRY	WET	REL. HUM.	DEW PT.	DRY	WET	REL. HUM.	DEW PT.	DRY	WET	REL. HUM.	DEW PT.	T. TOP	T. BOTTOM	WIND	VELOC.	PREC.	EVAP.	T. TOP	T. BOTTOM	WIND	VELOC.	PREC.	EVAP.
11	80	59	----	----	75	71	82	69	80	71	64	67	78	71	71	68	67	66	Se	Lt	0	0	72	67	Sw	Lt	----	.1
12	87	78	----	----	67	66	95	66	82	75	80	72	77	75	91	74	69	68	Sw	Lt	----	.1	74	69	Sw	Lt	----	.1
13	83	70	----	----	75	73	91	72	81	75	76	73	75	72	86	71	72	71	0	0	Lost		74	72	Se	M	----	.4
14	83	70.5	----	----	71	70.8	98	71	80	75	79	73	78	73	79	71	74	69	0	0	0	0	73	70	Se	Lt	----	.15
15	83	67	----	----	70.5	70.5	100	70.5	79	76	87	75	68	66.5	93	66	72	71	0	0	0	0	73	71	Sw	St	1.5	----
16	83	63	----	----	66	65	95	64	81	74	72	71	74	69	78	67	73	72	Se	Lt	Lost		75	73.5	Se	Lt	----	.3
17	73	62	----	----	67	64	85	62	65	63	90	62	71	69	90	68	73	73	0	0	----	.1	73	73	Se	M	hvy	----
18	75	62	----	----	64	64	100	64	74	71	86	70	68	66	90	65	72	71.5	Storm		hvy	----	71	71	----	----	hvy	----
19	72	52	----	----	61	63	95	62	64	61	85	59	63	61	89	60	70	69	----	----	----	.1	70	69	----	----	----	.2
20	74	53	----	----	57	56	94	55	70	65	77	62	69	63	72	59	68	68	----	----	0	0	71	70	----	----	----	.2
21	77	54	----	----	60	58	89	57		Lost			63	61	89	60	69	69	0	0	0	0	70	70	----	----	----	lost
22	81	53	----	----	64	61	85	59	79	71	68	67	72	67	78	64	70	69	0	0	----	.1	71	70.5	----	----	----	lost
23	84	59	----	----	62	61.5	97	60	80	74	76	72	74	71	86	70	70	69	S	M	T	----	73	71	----	----	----	.2
24	67.5	63	----	----	63	63	100	63	68	66	90	65	64	62	90	61	71	70	----	----	0	0	71	70	Ne	St	----	.1
25	66	57	----	----	59	58	94	57		Lost			64	62	90	61	70	69	----	----	----	.1	69	69	----	----	----	.1
26	68	56	----	----	60	59	94	58	67	64	81	62	62	62	100	62	68.5	68	Se	Lt	----	.1	68	66	----	----	.3	----
27	78	61	----	----	68.1	67.9	99	68	77	75	79	74	71	70	95	70	69	68	0	0	----	.1	70	70	----	----	.2	----
28	71	62	----	----	62	62	100	62	65	64.5	98	64	70	68	90	67	69	69	0	0	0	0	71	70	0	----	----	----
29	83	59	----	----	63	62	94	61	81	77	83	75	80	77	87	76	69	69	0	0	0	0	72	70	----	----	----	.1
30	83	68	----	----	69	68	95	68	79	76	87	75	75	73	91	72	72	70	0	0	0	0	75	72.5	----	----	----	.15
31	75	64	----	----	66	65	95	64	70	68	90	67	74	73	95	73	74	73	0	0	----	.15	75	73.5	----	----	----	.5

St—strong. M—Medium. Lt—Light wind.

CONTROLLING FAULT SYSTEMS IN IOWA.

CHARLES KEYES.

With its even plains surface, the infrequency of bed-rock exposures, and the universal presence of thick till or loess mantles, detailed geologic mapping of the prairie states is attended by many inherent difficulties not met with in more broken country. In consequence of the existence of these unusual conditions the consideration of possible noteworthy geotectonic features in the region is largely neglected. Anything beyond a few of the most obvious local characters completely fail of record. Over a very large part of the Mississippi basin the tectonics are commonly treated as if there were none at all. It seems to suffice to regard the strata as essentially flat-lying and as having no pretense to deformation of any kind. In Iowa, for instance, beyond the general assertion that the foundation rocks dip gently to the southwest no further note is made of the local or broader tectonic characters.

Lately, both in our own state and in neighboring states, the neglected problems in regional tectonics have been attacked from new and unexpected quarters. Novel data have been obtained. Long known but isolated facts have been reviewed, reinterpreted, and recorrelated. The trend of most fruitful inquiry has been pointed out. In Iowa, especially, results quite surprising have been reached. Attention already has been directed[1] to the Triassic mountain-building which took place within our boundaries. Particular interest also attaches to the recent determination[2] of the distinct synclinorial character of the Iowa coal basin. Now note must be made of another instructive phase of the regional tectonics and the discovery of what appears to be two well-defined systems of faulting on a large scale that has heretofore eluded detection.

The lines of faulting of the two systems trend nearly at right angles to each other. In the system which prevails in the eastern part of the state the direction of fracture is northwest and

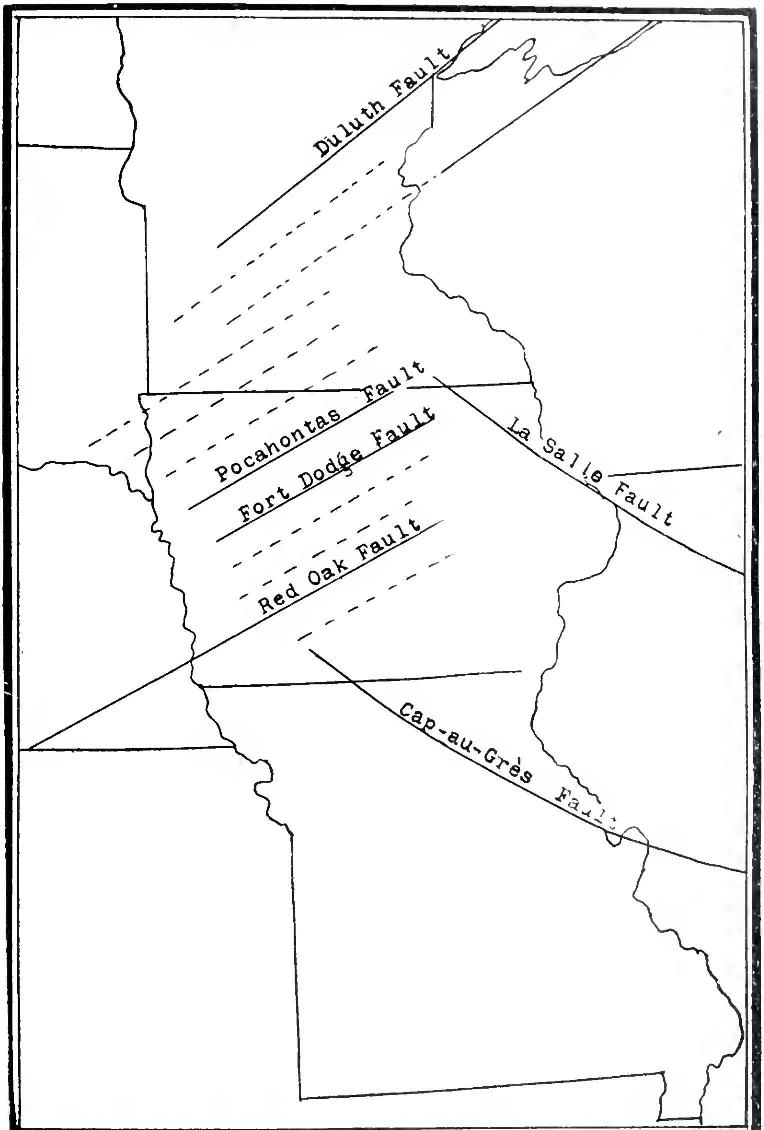
[1]Proc. Iowa Acad. Sci., Vol. XXI, 1914, p. 181.
[2]Ibid., Vol. XXII, 1915, p. 268.

southeast. The amount of displacement is large. The spacing is wide. The ruptures are long and somewhat curved. In the other system, which is confined to the western portion of the state, the value of the movement figures is not nearly so great as in the case of the other; yet it is still quite notable. The space beween successive faults represents a distance of about twenty-five miles. Both systems of faults appear to have greater displacement values outside of the state and to vanish within the boundaries of our commonwealth. The faults extend laterally far into neighboring states. (Plate IV.)

At this time it is not necessary to go exhaustively into descriptive details concerning the individual faults, since these features are in another connection subject of extended discussion. The most conspicuous of the displacements is the Cap-au-Gres fault. It is the most notable line of recent dislocation found anywhere in the Mississippi valley. Its salient features are best displayed on the Mississippi river near the mouth of the Illinois river. The sandstone headland which marks its position there has been a prominent landmark to early *voyageurs* and rivermen for a period of more than two and a half centuries. The upturned edges of the strata constitute one of the most extensive and complete geological sections on the continent. Within a distance of one short mile along the river bluff, at Folley station, the entire Paleozoic succession, from Cambric dolomites to Coal Measures, is exposed. Measurements indicate a vertical displacement of more than 1,000 feet. So admirably are the disturbed rocks displayed that a photographic print of the bluff clearly retains all the structural features.[3]

The line of the Cap-au-Grès rupture extends from Leon, in southern Iowa, to Vincennes, Indiana, a distance of 400 miles. At its eastern extremity the fault passes into a fold, probably of monoclinal rather than anticlinal character, that gives rise to the great oil reservoir of eastern Illinois and western Indiana. The western extension likewise passes into a fold which furnishes the most favorable conditions in our entire state for the occurrence of oil and gas. At the southern boundary of Iowa the line of this fault is conspicuously marked on the surface of the ground by a long eastward protrusion of the Bethany limestone, the basal terrane of the Missourian series. This tongue carries the Bethany formation a distance of fifty miles beyond

[3]See Proc. Iowa Acad. Sci., Vol. V, 1898, p. 58.



Major faults in Iowa.

its normal eastern boundary as usually mapped. As it enters Iowa the Cap-au-Grès fault has a displacement of 100 feet, so that here it is still a fracture of considerable moment.

Another notable fault-line, which merits fuller investigation than has been heretofore accorded it and about which so far as Iowa is concerned relatively little is yet definitely known, exists near Dubuque. It has a throw of fifty to seventy-five feet. One reason for its not being better understood doubtless is the fact of its position for many miles in the channel of the Mississippi river. According to the maps of Illinois this fault-line appears to be really the northwestern extension of the great La Salle fault, which at the town of La Salle has a displacement of quite 1,000 feet. Illinois geologists claim that the La Salle fault has a north and south trend; but the geological maps of the region clearly indicate otherwise, and many other recorded facts fully corroborate the testimony of the maps.

Between these two great fault-lines are several rather sharp folds which may pass elsewhere into faults. None of these has been examined yet in detail. They may prove to be regularly spaced and thus form a part of a definite fault system.

It is, however, to the remarkable fault system of the western part of the state that attention is here especially directed. Two faults in particular merit full notice at this time because of the fact that their discovery necessitates extensive rectification of geologic boundaries. There are, also, economic bearings which are of great local importance. The two most instructive ruptures of this western system are the ones passing near Red Oak and near Fort Dodge.

For such a profound fracture, with its maximum displacement of not less than 400 feet, the Red Oak fault makes singularly inconsequential impress upon the local relief expression. In one direction it appears to extend beyond the city of Des Moines; in the other to Hebron, Nebraska—a distance of 300 miles. Its features are best displayed at its crossing of the Missouri river, at Wyoming, a short distance above Nebraska City. When the disturbance was first noted at this point it was thought to represent a sharp monoclinal fold; and it was so interpreted by Professor J. E. Todd.[4] Later investigation on the Iowa side of the river, near Truman, showed that there was

[4]Proc. Iowa Acad. Sci., Vol. I, 1890, p. 58.

practically no tilting of the strata, but that the lower beds on the north side of a given point abutted higher layers of the south side.

The detection of this notable fault-line fully explains why, during the attempt to map geologically Montgomery county, the Cretacic formations were so well exposed throughout the southern half of the county, but were apparently entirely absent in the northern part. Planation had entirely removed the higher Mesozoic beds on the north, but had not touched those to the south, where they were deeply depressed and thus escaped obliteration. Another hitherto inexplicable fact, which now appears to be satisfactorily cleared, is the abrupt change of lithologic character which has been long known in the Des Moines river section a few miles north of the city of Des Moines. For more than a generation this had been one of the most perplexing problems in Iowa geology.

The Fort Dodge fault is particularly noteworthy because of the fact that to it the great Iowa gypsum field directly owes its preservation; and important chalk deposits exist as outliers eighty miles east of their normal outcrops. As recently acquired the details on this dislocation are unusually full and may be with advantage summed up here. They are all displayed in an exceptionally clear manner within the limits of the city of Fort Dodge.

The abrupt termination of the thick gypsum bed at the Cummings quarry, in the south bluff of Soldier creek, in north Fort Dodge, and its replacement at the same level on the north side of the narrow valley by the St. Louis limestone and coal measures calls at once for a more critical examination of the causes therefor than has been hitherto given to the phenomena. In this district there is a general rising of the limestone towards the north; but in the same direction a marked falling of the gypsum. At the mouth of Soldier creek the gypsum layer comes down to a level below that of the creek bed. It is this fact mainly that has in the past given rise to the inference that the gypsum finally rests directly upon the limestone, especially since the latter crops out in the banks of the creek and in the ravines within a distance of a few hundred yards beyond the last known gypsum exposure.

About three-fourths of a mile upstream from the Cummings locality, in Soldier valley, near the new brick plant, several especially instructive exposures are now displayed. The valley here is quite deep and narrow. There are, on one side of the creek, the ruins of an old lime-kiln. The St. Louis limestone, which was formerly quarried at this point to supply the kiln, rises about twenty feet above the bed of the stream. Two hundred feet to the southeast, in another bend of the creek, the gypsum plate, overlain by thirty to forty feet of reddish, sandy shale, outcrops at water-level. Northwest of the lime-kiln, about 400 feet, on the opposite side of the Soldier gorge, in the clay pit of the brick plant, forty feet of coal measures are well displayed. It seems hardly possible that the gypsum-plate, here twenty-five feet in thickness, should wedge out abruptly and completely in so short a distance.

The most illuminating section of all in the entire region is that at the south end of the long narrow ridge which separates Soldier valley from that of the Des Moines river. Two exceptionally fine artificial exposures supplement the natural outcroppings of strata. On the one side of the ridge the excavation for one of the abutments for the country highway viaduct over the Soldier gorge discloses, in fresh, clean face, over seventy-five feet of the pink shales which immediately overlie the gypsum. The latter lies in the bed of the creek a short distance away. The Kohl Brewery section is near by, although now nearly completely obscured by talus. The two sections, which are easily matched by the sandstone ledges, together give the following sequence:

SECTION AT LOWER VIADUCT OVER SOLDIER CREEK.

		Feet
8.	Till, gray and pebbly	10
7.	Shale, light reddish, sandy, banded	35
6.	Sandstone, soft, buff, calcareous, massive	5
5.	Shale, pink and white, sandy, in alternate layers	25
4.	Sandstone, massive, buff	2
3.	Shale, bluish	2
2.	Shale, brown, sandy, with gypsum layers	7
1.	Gypsum, massive (exposed)	10

This exposure is the most extensive one of the pink shales yet disclosed. The thickness of the latter is therefore at least 100 feet.

On the opposite, or north side of the high ridge, is the huge open clay-pit of the Fort Dodge Brick and Tile Company. The bottom of the excavation is nearly, if not quite, down to the St. Louis formation; and is about thirty feet above the level of the water in the Des Moines river near by. Fully seventy feet of shale are exposed in clean section, which presents the following sequence of beds:

SECTION AT CLAY-PIT OF FORT DODGE BRICK AND TILE PLANT.

		Feet
9.	Till, ashen, with pebble bands	15
8.	Shale, blue, yellow and variegated	18
7.	Sandstone, gray, massive	2
6.	Shale, black and gray, with coal-seams	11
5.	Shale, white (fire-clay)	2
4.	Shale, light-colored and variegated	15
3.	Shale, dark-colored, partly hidden at base	25
2.	Sandstone, coarse, conglomeratic, ferruginous	1
1.	Limestone, gray	30

In cross-section, the ridge appears as represented below (figure 6), in which the gypsum-plate is noted to lie about thirty feet beneath the level of the top of the adjoining St. Louis lime-

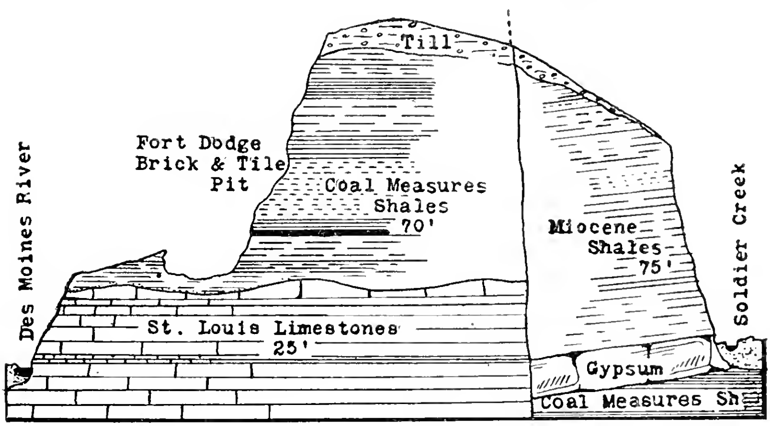


Fig. 6—Details of Fort Dodge fault.

stone, and nearly one hundred feet beneath the top of the coal measures of the clay-pit. In stratigraphic level there is thus a discrepancy of more than one hundred feet between corresponding parts on the two sides of the ridge.

On the west face of the ridge, in a railway cutting, near a point where on the same level the pink shales appear to be abruptly replaced by the dark shales of the coal measures, an inconsequential faulting of the first mentioned beds is plainly discernible. This slight fault has a throw of about six feet. It is suggestive of the possibility of the greater displacement being of the distributive order instead of being a single simple break in the stratigraphic continuity.

At the old stone wagon bridge over Soldier creek, one-half mile above the lower viaduct, and immediately north of the Rock Island railway station, there is a singular physiographic suggestion of notable faulting. For a distance of several miles before reaching this bridge the creek flows in a deep, narrow gorge. At the point where the bridge spans the waterway the latter cuts sharply into the hard St. Louis limestone, so as to form a small canyon thirty feet wide and twenty feet in depth. The abutments of the bridge are the two walls of the canyon. Less than one hundred yards below the bridge the limestone, although standing thirty feet above the creek bed, abruptly disappears. The Soldier gorge opens out into a broad, flat-bottomed amphitheatre a thousand feet wide and half a mile long, the flat forming an area sufficiently ample for utilization by the railroad for its local yard purposes. The amphitheatre is excavated entirely in the friable sandy shales which overlie the gypsum. No sign of the St. Louis limestone is to be seen save the point on the north side where the creek debouches from its canyon.

On the west side of the Des Moines river, opposite the mouth of Soldier creek, new and important data of an exact kind are now available bearing upon the points in question. The extensive excavations of the Fort Dodge Clay Works, the construction of the Omaha extension of the Chicago Great Western Railway, the drilling of numerous deep wells, and the opening up to inspection of many other sections, disclose a number of instructive facts which supply the long missing links in the solution of the gypsum puzzle. On this side of the river the gypsum plate retains the same gentle slope to the northward, as it does on the east side of the stream.

It is shown by drill-holes and by excavations that the gypsum bed, fifteen to twenty feet in thickness, lies between seventy-five and ninety feet beneath the upland prairie surface. This overburden is composed chiefly of glacial till. Beneath the gypsum layer are sixty to eighty feet of shale—the coal measures; then the St. Louis limestone. The great thickness of the shale section carries the limestone a considerable distance beneath the level of the water in the Des Moines river, a mile and a half below the mouth of Lizard creek and half a mile below the mouth of Soldier creek. Yet at the mouth of the Lizard the limestone is abruptly encountered seventy feet above the water-level. It is an early observation of C. A. White and others that no outcrops of gypsum occur for some little distance below the mouth of Lizard creek; it is also a matter of early record that southward beyond the points just mentioned the gypsum suddenly appears in outcrop well up in the bluffs. For these anomalies there has never been any adequate explanation offered. As appears farther on, these features, together with others, conclusively point to either abrupt flexing of the strata, or notable dislocation in the continuity of the layers. Either suggestion is a wholly unexpected phenomenon in this district. In a region such as Iowa, where there is seemingly so little orogenic disturbance, neither sharp folding nor extensive faulting is ever appealed to. However, several extensive breaks in the Iowa rocks are now known; and other geotectonic features come to light which give this phase of the State's geology a new trend.

On the geologic map of Webster county,[5] the nearly straight line which the north margin of the gypsum-bearing field makes is in itself suggestive of structural rather than erosional causes. This aspect of the areal limits was not thought of at the time the map was drawn. The fact of its location shows how accurately is the delineation notwithstanding the circumstance that the reason thereof was unknown.

As shown by outcrops and numerous well-sections located near this line on either side, there is a marked discordance in the meeting or matching of the various strata.

As already indicated, the amount of displacement at the intersection with the Des Moines river is not less than 100 feet. This may or may not be the maximum throw; probably it is not. Several features point to a greater development of the fault towards the southwest.

The length of this great rent in the earth's crust is not yet with accuracy determined. That it extends from Clarion, in Wright county, to Wall Lake, in Sac county, a distance of eighty miles, seems certain. That it is traceable beyond these points is quite probable. It is safe to say that this fault is not less than a hundred miles long.

[5]Iowa Geol. Surv., Vol XII, 1902, p. 192.

With the recognition of this fault-line a host of features relating to the distribution of the formations of the region, hitherto puzzling or uncertain of determination, are fully explained.

North of Fort Dodge there are evidences of another fault which passes through Pocahontas and which has a throw of about eighty feet. The horizontal distance between the two lines of displacement is approximately twenty-five miles. This figure suggests the spacing value of the whole system. Plotting upon the map of the state other lines to mark possible positions of other faults we find abundant indications of the presence of such features. One of these passing a short distance south of Ames points to the isolated protrusion of Early Carbonic limestones being really produced by differential movement along a line of rupture.

It is a well known fact established through extensive experience in mining operations that when the interval between two parallel faults is determined that other faults are to be expected at like intervals. This circumstance is traceable directly to the nature of the tortional strains which rock-masses undergo. Whether or not such a high spacing value as twenty-five miles is actually possible remains to be determined theoretically. The problem is readily susceptible of mathematical demonstration as in the cases of fault systems of much closer patterns as recently noted by G. F. Becker[6]; and it would be exceedingly instructive to apply the principles involved to the Iowa situation.

In any case the general geological mapping of the state requires fundamental rectification.

[6]Bull. Geol. Soc. America, Vol. IV, 1893, p. 13.

TERRANAL AFFINITIES OF ORIGINAL CHOUTEAU LIMESTONE.

CHARLES KEYES.

In all the Mississippi valley there is no geologic formation that is so misunderstood, or so illy considered as regards its stratigraphic relations, as the massive, buff limestone terrane immediately underlying the Burlington limestone of Missouri and Iowa. Originally noticed by Prof. G. C. Swallow,[1] in 1855, as a thick, homogeneous lithologic unit typically developed in central Missouri along the northern flanks of the Ozark dome, and extended into other parts of the state as the uppermost member of a tripartite "Chemung" group, little mention is later made of it.

When, a generation after Swallow, Prof. H. S. Williams[2] revived the title it was with an entirely different meaning; the term then applying not to a terrane at all but to a fauna carried by all of the Early Carboniferous rock-section beneath the Burlington horizon. In this he followed Prof. G. C. Broadhead[3] who had, in 1874, proposed the name Chouteau Group to take the place of Chemung Group of the previous accounts of the region. In the earlier reports of the present Geological Survey of Missouri[4] the term, in Swallow's original sense, is repeatedly recognized. Prof. E. M. Shepard reports[5] the formation in its typical development to occur in Greene county, in southwestern Missouri. In the north, in Iowa, the Chouteau limestone is not generally recognized by title, yet it is several times so called in the central part of the state.[6]

In Illinois, where the Chouteau limestone is not known to be represented, the terrane is commonly merged with the Kinderhook group, as is done by F. B. Meek and A. H. Worthen[7]. Through the wide usage of the latter title Swallow's name is

[1]Missouri Geol. Surv., 1st and 2d Ann. Repts., p. 102, 1855.
[2]Bull. 80, U. S. G. S., p. 169, 1891.
[3]Missouri Geol. Surv., Rept. 1873-4, p. 26, 1874.
[4]Missouri Geol. Surv., Vol. IV, p. 57, 1894.
[5]Ibid., Vol. XII, 1898.
[6]Iowa Geol. Surv., Vol. XXII, p. 154, 1913.
[7]Am. Jour. Sci., (2), Vol. XXXII, p. 288, 1861.

gradually lost sight of. Whenever reference is made to the uppermost member of the succession it is called the Kinderhook limestone[8].

Singularly enough, since Swallow's time, the Chouteau limestone in its original locality has never been carefully studied. Few persons have taken the opportunity to inspect the type-sections. The eastward attenuation of the formation, in eastern Missouri, where it again reaches sky after burial in a broad syncline, has made the terrane appear to be an unimportant member of the so-called Kinderhook section.

In recent years a large number of deep-well records enables the underground extent and thickness of many formations in Missouri and Iowa to be accurately traced and determined far from their lines of outcrop. Among the terranes of this class is the Chouteau limestone. The data bearing upon its stratigraphic relations permit it to be clearly delimited from Minnesota to Arkansas, a distance of more than 600 miles. As a definite lithologic unit and a sharply delimited terrane the Chouteau limestone presents some features of more than local interest in general geologic correlation.

At the original locality, at Chouteau Springs, central Missouri, and at neighboring places in Saline, Cooper and Pettis counties, the interval of 125 feet between the undoubted Devonian Callaway limestone and the Early Carboniferous Burlington limestone is occupied by grey limestones. This circumstance leads Professor Stuart Weller[9] to regard the original Chouteau section as representing the entire Kinderhook succession of other parts of the Mississippi valley. Swallow[10] from the first recognized the fact that the entire section of his "Chemung" (Kinderhook) group, which in other parts of Missouri is a three-fold division, is in the central portion of the state an unbroken sequence of limestone layers. Nevertheless, he considers[11] the lower twenty feet as the Lithographic (Louisiana) limestone division; and the middle part as replacing the Vermicular (Hannibal) shales of elsewhere.

Recent observations show that Swallow is mistaken only in a single point. Not finding the Vermicular shales in distinct development in Cooper county as elsewhere he assumes them to be

[8]Iowa Geol. Surv., Vol. I, p. 56, 1893.
[9]Bull. Geol. Soc. America, Vol. XX, p. 321, 1909.
[10]Missouri Geol. Surv., 1st and 2d Ann. Repts., p. 195, 1855.
[11]Ibid., p. 103.

replaced by limestone. In other parts of Missouri he clearly considers the Chouteau limestone as the upper member of his "Chumung" group.

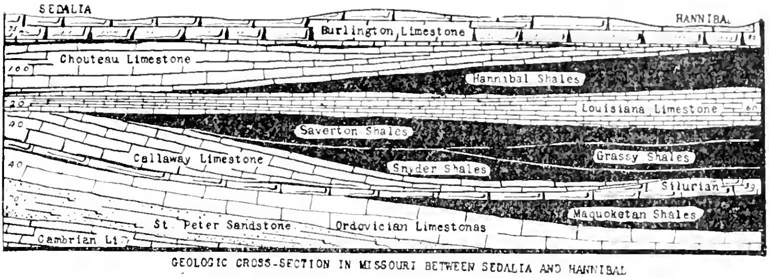


FIG. 7.

Two geological cross-sections constructed at right angles to each other and intersecting at Chouteau Springs quickly set to rights all the conflicting notions of the past fifty years concerning the stratigraphic relations of the Chouteau limestone. One cross-section extends from Hannibal (near Kinderhook, Illinois) on the Mississippi river, to Sedalia, in Pettis county, a distance of one hundred thirty miles (figure 7). The other section, fifty

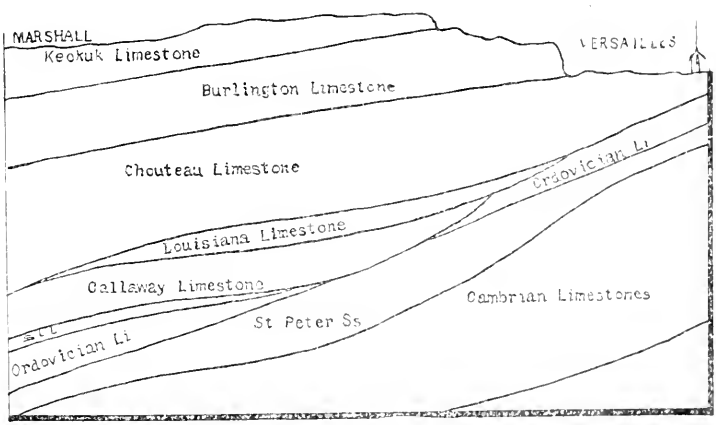


FIG. 8—Chouteau terrane at type locality.

miles in length, traverses Saline, Cooper and Morgan counties, from the town of Marshall to that of Versailles (figure 8). Both sections are checked at frequent intervals by rock exposures and by well records.

As recently shown [12] the Early Carboniferous section beneath the Burlington limestone, in northeast Missouri, embraces more than the three members originally ascribed to it. Two other members properly belong to its base. This section presents the following succession:

	Feet
Burlington limestone	
Unconformity.	
Chouteau limestone	30
Hannibal shales	75
Louisiana limestone	50
Saverton (blue) shales	50
Grassy (black) shales	40
Unconformity.	

By reference to the principal cross-section (figure 8) it is noted that the Chouteau limestone, which is a hundred feet thick at the typical locality, gradually becomes thinner until it vanishes completely just before the Mississippi river is reached, where the Burlington limestone lies immediately upon the Hannibal shales. On the other hand the Hannibal shales, which are seventy-five feet in vertical measurement at the east end of the section, decline in thickness westward until by the time Cooper county is reached they disappear by attenuation, and the Chouteau and Louisiana members come together. The last mentioned limestone, which is sixty feet thick at the Mississippi river, also becomes reduced to the west until in Cooper county it has only about one-third its original measurement. It appears, therefore, that Swallow[13] was actually correct in assigning the lower twenty feet of the Cooper county "Chemung" (Kinderhook) to the Lithographic (Louisiana) limestone.

The Saverton shales, Grassy (black) shales, and the Snyder (Devonian, Lime Creek) shales also chance to thin out towards the west, so that at the western border of Cooper county the Carboniferous limestones rest directly upon the Callaway (Devonian) limestones. Moreover, the Buffalo (Maquoketan) shales, which are well developed on the Mississippi river, vanish completely within a distance of fifty miles of that stream. In central Missouri there is, then, a rock succession extending from the St. Peter sandstone to the Coal Measures that is without a single shale or sandstone layer to relieve the limestone uniformity. This is the reason why it is so difficult usually to interpret satis-

[12] Am. Jour. Sci., (4), Vol. XXXVI, p. 160, 1913.
[13] Missouri Geol. Surv., 1st and 2d Ann. Repts., p. 103, 1855.

factorily the deep-well records of the region; and why driller's logs are really more accurate than is commonly claimed for them.

Viewing the Chouteau limestone strictly as a lithologic unit, delimited with unusual sharpness as it happens, several points are to be especially emphasized. The eastern attenuated margin of the formation very nearly coincides with the course of the Mississippi river from the mouth of the Iowa river to that of the Missouri river. Nowhere does the terrane appear actually to touch the banks of the great stream. Chouteau limestone is reported to be represented at several points on the river, as at Louisiana[14] and Hannibal, in northeast Missouri, and at Burlington[15], Iowa. The thin bed referred to at these places may represent an earthy phase of the Burlington formation, for in this region the latter formation actually rests in marked unconformity upon the Hannibal shales.

In Iowa, north of the original locality, the Chouteau limestone commonly goes under the title of Kinderhook Beds[16]. The formation becomes thicker, reaching a measurement of one hundred fifty feet in the central portions of the state. Near the Minnesota boundary, where the Paleozoics are upturned as one limb of the now truncated arch which once formed the Siouan mountains, the thickness is even greater. The formation, after crossing this great Triassic flexure, probably extends northwestwardly far into Canada.

Between the Missouri river and the Minnesota state-line, a distance of more than three hundred miles, the Chouteau limestone has a thickness of one hundred to one hundred fifty feet. Numerous deep-well records in this belt enable the limestone plate to be traced for a distance of seventy-five miles from its outcropping.

The axis of the broad syncline lying between Chouteau Springs and Hannibal extends southwestward over the present Ozark dome, which of course did not exist in Early Carboniferous times. When the Kinderhook rocks again appear in southwest Missouri the same tripartite character as presented in the north part of the state seems to hold. At Springfield Swallow's original interpretation[17] of the sequence appears to be in the main correct. With the elimination of the so-called Devonian beds of the same

[14]Am. Jour. Sci., (3), Vol. XLIV, p. 449, 1892.
[15]Bull. Geol. Soc. America, Vol. III, p. 285, 1892.
[16]Iowa Geol. Surv., Vol. I, p. 56, 1893.
[17]Missouri Geol. Surv., 1st and 2d Ann. Repts., p. 103, 1855.

section Prof. E. M. Shepard's recognition[18] of the Chouteau, Hannibal and Louisiana members also seems to be fully substantiated by recent observations. Still later Prof. Stuart Weller,[19] from a critical study of the fossils found in the so-called Northview sandstone (Hannibal), furnishes indubitable evidence in support of the early interpretations. By showing the identity of the Northview fauna with that of the beds lying immediately beneath the Burlington limestone at Burlington, Iowa, correlation with the Hannibal shale seems complete. At Burlington the latter are known to cover the interval of fifty feet between the base of the Burlington limestone and the horizon of the Louisiania limestone.[20]

The correlation of the original Chouteau limestone with the recently proposed Fern Glen formation, twenty miles west of St. Louis, presents many uncertainties. South of the Missouri river the lowermost Burlington limestones lose their characteristic lithologic features. They no longer remain crinoidal breccias. Texturally they strongly resemble the typical Chouteau and Louisiana limestones. The red coloration, so conspicuous northward at Burlington city, persists. As described in detail by Professor Weller[21] the fauna appears to be identical with that of the red Burlington beds occupying the lower twenty to thirty feet of the Iowa section. Aside from a few weeks' collecting in the typical Lower Burlington strata, by the late Doctor Wachsmuth and myself, no crinoids of consequence have been obtained at Burlington in forty years, so that the determination of the zonal distribution of these forms has not been recently possible. The figures of the Fern Glen fossils seem to represent leading species which Niles and Wachsmuth[22] long ago listed as characterizing their Lower Burlington division of the Iowa section. These facts are admirably brought out by Professor Weller[23] in his late discussion of the affinities of the Fern Glen faunas.

[18] Ibid., Vol. XII, p. 49, 1898.
[19] Journal of Geology, Vol. IX, p. 130, 1901.
[20] Am. Jour. Sci., (4), Vol. XXXVI, p. 161, 1913.
[21] Geol. Soc. America, Vol. XX, p. 265, 1909.
[22] Am. Jour. Sci., (2), Vol. XLII, p. 95, 1866.
[23] Bull. Geol. Soc. America, Vol. XX, p. 265, 1909.

COAST RANGE CIRQUES OF THE SKEENA BASIN.

CHARLES KEYES.

(ABSTRACT.)

In British Columbia the manifold aspects of alpine glaciation are displayed as they are perhaps nowhere else on the face of the globe. Northward as they approach the southern tip of Alaska the lofty Cascade ranges of the United States pass into coast ranges; and the coast ranges of the south run into the sea, giving rise to the countless islands which are so characteristic of this part of the Pacific coast.

At a point a few miles from the Alaskan boundary the Skeena river, after cutting a deep canyon entirely through the coast ranges, enters the sea. This river is one of the noble streams of the continent. On either side the mountains rise abruptly to elevations of 3,000 to 4,000 feet. The permanent snow-line is here sufficiently low to render it easily accessible. Cirque phenomena are developed to a wonderful extent.

Glaciers are in all stages of growth and decline. On every hand their work is open to the most detailed scrutiny. Even from the railway train many of the different aspects are easily viewed. For a distance of more than 100 miles the rail journey lies uninterruptedly in the midst of clearly observable cirque phenomena. In few places in the world are all the details corroborating the Johnson hypothesis of cirque formation so well displayed.

AN OUTLIER OF THE SO-CALLED CLINTON FORMATION IN DUBUQUE COUNTY, IOWA.

JESSE V. HOWELL.

During the summer of 1914 a considerable amount of grading was done at the forks of the road on the west side of Lora Hill, seven miles west of Dubuque. As a result of this work there was exposed along the road a band of peculiar reddish clay from one to two feet in thickness, underlain by the characteristic gray-green, plastic clay-shales of the Upper Maquoketa formation. The red clay is much less plastic than the underlying green shales, but is remarkable chiefly for the fact that it is composed largely of iron oxide and contains great numbers of small, rounded concretions or oölites. Also imbedded in this deep red clay are: a. numerous pebbles of smooth, polished chert, b. rounded fragments of indurated material similar to that of the clay, and c. rounded fragments of slightly iron stained shale.

The fragments belonging to the second class are crowded with oölites, but contain no fossils. Weathering has so softened the material of both oölites and matrix that it is not possible to polish the fragments for satisfactory microscopic study.

When examined under the low power of the microscope the oölites are seen to possess the same concretionary structure which characterizes similar bodies in the "Clinton" formation of Wisconsin and the true Clinton ore of the eastern states. The individual layers or coatings separate rather readily, exposing, usually, a more or less definite nucleus. Many of the oölites on being dried, show somewhat glazed surfaces, especially after removal of the outer layers.

Particularly in those portions of the clay near the contact with the unstained green shale, the red clay contains many fossils. All the forms appear to be of Ordovician age, and it seems probable that they come from the green shale, for a majority of the specimens are not replaced by iron. Two individuals, apparently sponges, are composed largely of iron oxide, but the structure has been so destroyed by weathering that their identity is not certain. Most of the fossils are silicified and all of them are broken and comminuted.

Qualitative chemical examination of the red clay reveals the presence of ferrous and ferric iron, carbonates, calcium, silica and aluminum. The oölites are largely siliceous but contain also calcium carbonate and iron.

Similar outcrops of the ferriginous material are found on the east side of Lore Hill at elevations which indicate that the bed lies in a practically horizontal position and probably is continuous throughout the hill. In one of these outcrops fragments of impure, cherty dolomite occur just above the iron band.

On the north side of the hill, twenty-one feet above the iron band, a small quarry exposes typical Niagaran dolomite containing the following fossils:[1]

Halysites catenulatus.
Lyellia (probably americana).
Strepte'asma sp.
Cystoid (plate only).
Plectambonites sp.
Orthis flabellites.
Dalmanella elegantula.
Platystrophia daytonensis.
Leptaena rhomboidalis.

Evidently then the iron band lies at or near the contact of the Niagaran and Maquoketa. It is possible that most of the twenty-one feet concealed may belong to the recently described Alexandrian Series.[2]

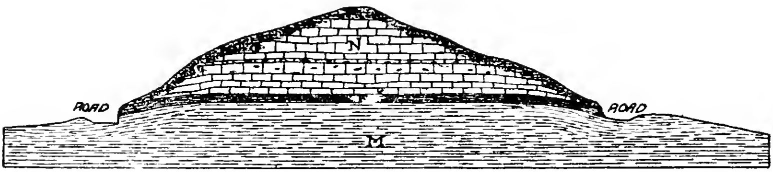


Fig. 9.

The diagram (figure 9) illustrates the probable conditions at Lore. Since the undisturbed layers are nowhere exposed it is not possible to ascertain the actual conditions. The thin band of ferruginous oölite lies between the soft, plastic shales of the top of the Maquoketa and the massive dolomite of the lower Niagaran. Probably the iron band originally was indurated, and this may yet be the condition at some distance within the

[1]Identified by Professor T. E. Savage, of the University of Illinois.
[2]Savage, T. E., Stratigraphy and Paleontology of the Alexandrian Series: Bull. Ill. Geol. Survey No. 23, 1913.

hill. But as weathering has continued inward from the sides of the hill the iron ore has softened and slumped with the soft shales underlying it. The slumping undoubtedly is aided by the pressure of the dolomites above. Considerable mingling of the two layers has taken place, and the division line between shale and iron band is not always definite.

CORRELATION.

The stratigraphic position of the oölitic band at Lore is practically identical with that of the so-called Clinton iron ore at Mayville and other points in eastern Wisconsin, as described by Chamberlin.[3] The Wisconsin ore rests on the eroded surface of the Cincinnati (Maquoketa) shale, and it too contains fossils of Maquoketa age which Chamberlin considers to have been mixed with the ore by the action of the glacial ice. Here also there is more or less mingling with the underlying clay shale, although the division in general is definite.

Thwaites[4] has described the "Clinton" ores of eastern Wisconsin as follows:

————an essentially unaltered sedimentary deposit which occurs in broad lenses in eastern Wisconsin, between the overlying Niagara dolomite (Silurian) and the underlying Maquoketa ("Cincinnati") shale (Ordovician). The lenses vary greatly in thickness, one of 55 feet being the thickest known. On the other hand their extent is so meager that by far the greatest portion of the beds at the ore horizon show not even a trace of the "Clinton" ore.

Crane[5] speaks of the presence of a layer of red, oölitic iron ore in the Silurian of Holt county, Missouri, and suggests that it probably is of Clinton age (op. cit., p. 48). The member, however, was studied only in the material from a deep drill hole and the description is very incomplete.

Savage and Ross[6] have recently studied the "Clinton" deposits of eastern Wisconsin, and have found in the ore numerous fossils which indicate a closer relationship to the Ordovician than to the Silurian. They consider the ore to have been deposited in late Maquoketa time in local basins formed after the withdrawal of the main Maquoketa sea. The name "Neda Iron Ore" is proposed as a substitute for the apparent misnomer "Clinton Ore."

[3]Chamberlin, T. C., Geology of Wisconsin, Vol. II, 1877, p. 331.
[4]Thwaites, F. T., Bull. U. S. Geol. Survey No. 540, p. 338.
[5]Crane, G. W., Missouri Bur. Geol. & Mines, 2d Series, Vol. X, pp. 148-149.
[6]Savage, T. E., and Ross, C. S., Am. Jour. Sci., Vol. XLI, 1916, pp. 187-193.

SUMMARY.

The marked similarity in lithologic character and stratigraphic position of the "Neda Iron Ore" and the oölitic material at Lore Hill seem to be sufficient ground for considering them parts of the same formation. It must not be assumed, however, that the sea in which they were deposited was continuous over the entire area between these widely separated outcrops. It is more probable, as suggested by Savage and Ross, that the deposition of the oölite took place in shallow, local basins which were at least intermittently connected.

It is not likely that the "Clinton" or "Neda" formation in Iowa will ever become of economic importance, for it appears to have a very limited areal distribution and but slight thickness. Further search along the Ordovician-Silurian boundary in northeastern Iowa may, however, reveal larger patches than the one described.

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A CORRELATION OF THE PENEPLAINS OF THE DRIFTLESS AREA.

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The conclusions reached in this paper in regard to the erosional history of the Driftless Area are the results of evidence secured from three sources: (1) Field work during the summer of 1915, carried on by the writer in the Baraboo district and the Richland Center quadrangle, Wisconsin, has furnished direct evidence for the northern portion of the area under consideration. (2) The literature on the subject has been used freely, the Lancaster-

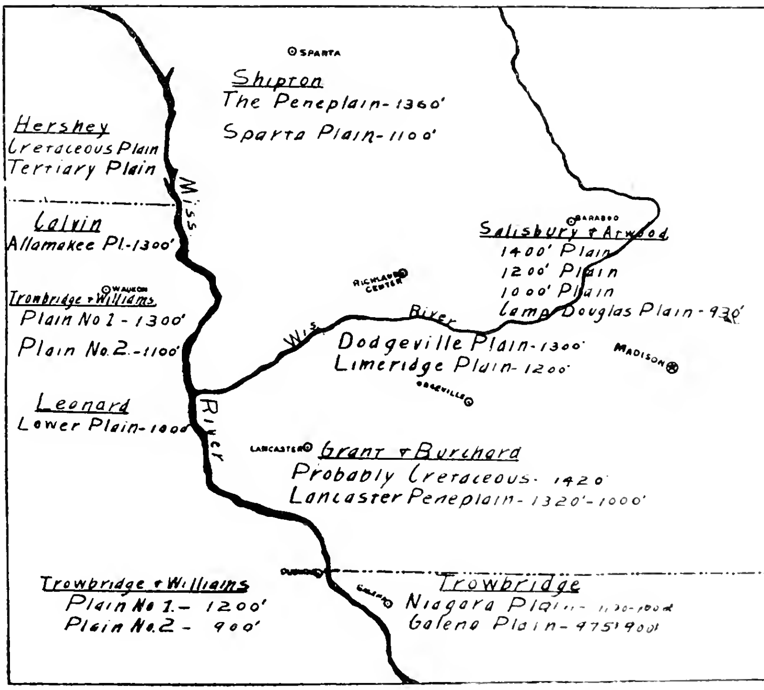

FIG. 10—A sketch map of the southern half of the Driftless Area, showing where and by whom work has been done on the upland plains and the general conclusions reached by the various workers.

Mineral Point folio by Grant and Burchard having proven especially valuable. (3) The details of the Elizabeth and Galena quadrangles were furnished by Prof. A. C. Trowbridge under whose direction the work has been carried on and whose advice was most valuable because of his intimate acquaintance with numerous localities in the Driftless Area.

FORMER WORK DONE.

For the past twenty years geologists who have worked in the Driftless Area have noticed the broad stretches of upland surface lying at approximately the same levels and harboring a civilization quite distinct from that of the deep, gorge-like valleys below the upland levels. In many cases the upland flats are so conspicuous as to be known locally as "prairies" on which are located villages, woodland areas, main roads, and many square miles of flattish, rolling country. These striking features have been described in the reports, barely receiving mention in some, whereas in other cases they have been treated as fully as available data permitted. It is not surprising that different men, working independently, at different times, and in widely separated portions of the Driftless Area did not round out their combined work into the harmonious whole. Accordingly, when an attempt is made to build the blocks as worked out into a unit, the wide divergence of conclusions is emphasized. The results of some of the most important work done and the geographical location of this work is shown is figure 10. For more detailed accounts of this work, see the brief bibliography following.

BIBLIOGRAPHY.

Bain, H. F., Zinc and Lead Deposits of Northwestern Illinois: Bull. U. S. Geol. Survey No. 246, pp. 13-16.

Calvin, Samuel, Geology of Allamakee County: Ia. Geol. Survey, Vol. IV, pp. 41-44.

Grant and Burchard, Lancaster-Mineral Point Folio: U. S. Geol. Survey, pp. 1 and 2.

Hershey, O. H., The Physiographic Development of the Upper Mississippi Valley: Am. Geologist, Vol. 20, pp. 246-268.

Howell, J. V., The Occurrence and Origin of the Iron Ores of Iron Hill, near Waukon, Iowa: Iowa Geol. Survey, Vol. XXV, pp. 33-69.

Leonard, A. G., Geology of Clayton County: Iowa Geol. Survey, Vol. XVI, pp. 220-233.

Salisbury, R. D., Preglacial Gravels on the Quartzite Range near Baraboo, Wisconsin: Jour. Geology, Vol. III, pp. 655-667.

Salisbury, R. D., and Atwood, W. W., The Geography of the Region about Devils Lake and the Dalles of the Wisconsin: Bull. No. V, Wisconsin Geol. and Nat. Hist. Survey, pp. 60-64.

Shipton, W. D., The Geology of the Sparta Quadrangle, Wisconsin: Master's Thesis State Univ. of Iowa, unpublished.

Trowbridge, A. C., Some Partly Dissected Plains in Jo Daviess County, Illinois: Jour. Geology, Vol. XXI, pp. 731-742.

Preliminary Report on Geological Work in Northeastern Iowa: Proc. Iowa Acad. Sci., Vol. XXI, pp. 205-209.

Physiographic Studies in the Driftless Area (abstract): Bull. Geol. Soc. America, Vol. 26, p. 76.

Trowbridge, A. C., and Shaw, E. W., Geology and Geography of the Galena and Elizabeth Quadrangles: Bull. No. 26, Illinois Geol. Survey, pp. 136-146.

Williams, A. J., Physiographic Studies in and around Dubuque, Iowa; Master's Thesis State Univ. of Iowa, unpublished.

Grant and Burchard describe one undoubted peneplain at 1,320 to 1,000 feet altitude which they call the Lancaster Peneplain, and mention a probable higher peneplain at about 1,420 feet. In the Galena-Elizabeth quadrangles, Illinois, Trowbridge found two peneplains, the Niagara plain at 1,170 to 1,100 feet, and a lower plain, the Galena plain at 975 to 900 feet. Likewise, field work by A. J. Williams and others under the direction of Professor Trowbridge in northeastern Iowa has established two peneplains. During the past summer W. D. Shipton found a peneplain and a probable lower one in the Sparta district of Wisconsin. Work by the writer in the Richland Center quadrangle, Wisconsin, seems to have established plains at two distinct levels. But all the work has not been so nearly harmonious, for Salisbury and Atwood have suggested the possibility of four peneplains in the Baraboo district and Hershey has given the number as five for the entire Driftless Area.

On account of the wide distribution of the areas studied it has not until now been possible to study the peneplains continuously over wide areas. At the present time, however, sufficient data are in hand to make possible the correlation of an area extending from Baraboo, Wisconsin, to Waukon and Dubuque, Iowa, and to the southern part of the Elizabeth quadrangle in Illinois.

STRUCTURE OF THE ROCKS.

The structure of the stratified rocks of the area is simple, with two exceptions. In general the strata form a gently-dipping monocline, in which the dip is about fifteen feet per mile in a southwest direction. But the quartzite formation at Baraboo is closely and intricately folded, and the Paleozoic strata in the southern part of the Elizabeth quadrangle have much steeper dips than the average for the Driftless Area. The seemingly simple monoclinal structure is further complicated by numerous gentle anticlines and shallow synclines, much jointing, and slight faulting.

THE UPPER PLAIN.

Of the two plains, the upper and older one will be discussed first. Reference to figure 11 shows that over the whole region there is much flat land which stands distinctly above the level of other flats and which forms remnants of a now much dissected plain. In drawing conclusions concerning the origin and correlation of this plain, several points are to be considered.

1. There are monadnocks standing above it, which are erosional remnants of a once still higher surface. This is well illustrated in the Baraboo region where Sauk Point at 1,620 feet above sea level and the west bluff at Devils Lake at 1,560 feet stand above the plain whose altitude here is 1,400 feet. The same relation is found at Waukon, Iowa, where a monadnock rises at least 100 feet above the uppermost plain. Also Platte Mounds and Blue Mounds may be considered to be monadnocks standing upon the upper plain.

2. At many points throughout the southern portion of the Driftless Area, patches of water-worn gravel are found on the upper plain. On the west bluff of Devils Lake several feet of these quartzose gravels are found on an old erosional surface and they are here closely associated with numerous potholes. These same gravels are found near Sparta, Wisconsin, at an elevation of 1,360 feet, they are known at Seneca, Wisconsin, and at Waukon, Iowa, they occur at 1300 feet altitude. This deposit of gravel, together with the remnants of higher land above the plain points to the previous existence of a surface which was in an imperfect state of peneplaination, with moderate relief, and whose streams had sufficient gradient to carry gravel such as is found.

3. The plain is not parallel with the underlying strata but cuts across the bevelled edges of dipping formations, rising stratigraphically to the south, as shown in figure 11. About Devils Lake and adjacent districts to the west, there are conspicuous levels at 1400 feet, which cut across the hard Baraboo quartzite, which dips at angles of 15° and more. If a line is drawn (the

FIG. 11. A structure section from Baraboo, Wisconsin, across the Denzer, Richland Center, Mineral Point quadrangles, to the south side of the Elizabeth quadrangle in Illinois. The vertical scale is exaggerated.

uppermost line, figure 11) from this 1400-foot level to the tops of the mounds in the southern portion of the Elizabeth quadrangle in Illinois, remnants of this plain between the two extreme points come to about the level of this line. South of Baraboo, the first great area of upland is an east-west ridge known as Military Ridge or locally known as Dodgeville Prairie because it is a gently undulating plain and almost treeless. This flattish surface averages 1200 feet in altitude, with occasional swells and knobs reaching higher levels. It is here underlain by Galena dolomite. Farther south the plain is found on the tops of numerous mounds and ridges at elevations of 1170, 1152, 1160 feet in the northern part of the Elizabeth quadrangle, at 1112, 1145, 1065, 1060, 1072 feet in the central part, and at 944, 964, 1027, 1004 and 1000 feet in the southern part of the quadrangle. In the northern part of the Elizabeth quadrangle the plain is on about twenty feet of Niagaran dolomite whereas in the southern part it is on more than 100 feet of the same formation.

The plain is seen to cut from Huronian quartzite at Baraboo across the Prairie du Chien, St. Peter, Platteville, Decorah, Galena, and Maquoketa formations, to the Niagaran formation at the south border of the Driftless Area. It slopes to the amount of six feet per mile in a direction 16° west of south.

4. The surface of the upper plain does not conform to the dip of the strata. The strata dip S. 45° W.; the surface of the plain slopes S. 16° W. The strata dip about fifteen feet for each mile; the plain slopes only six feet for each mile.

5. The surface of the upper plain wherever found is characteristically more dissected than the lower and younger plain. This is especially noticeable near Dodgeville. Near Highland, Wisconsin, the erosion is pronounced and the sharp draws show to what extent the original plain has been dissected.

6. It is not necessary to suppose that the plain is controlled by layers of resistant rock and therefore structural. On the contrary the features as found in the field are exactly what would be expected of a partly dissected peneplain. Wherever the less resistant rocks, like the Maquoketa shale, formed the original surface, they have been more eroded than the more resistant formations, whose surfaces are left to form the remnants of the plain today.

THE LOWER PLAIN.

There are considerable areas of flat land throughout the region which lie at distinctly lower levels than the flats referred to the upper plain (see the lower of the two straight lines in figure 11). In the Baraboo district west of Devils Lake, the lower plain is extensively developed at 1200 feet altitude, or 200 feet lower than the upper plain in the same locality. In the Richland Center quadrangle there is a remarkably flat area, in places almost untouched by stream work, which is seven miles long and as much as two and one-half miles wide in places. South of the Wisconsin river the lower plain is well developed at Lancaster where it has an altitude of 1100 feet, and still farther south it is ideally represented in the Elizabeth quadrangle at 975 to 900 feet. This plain has been traced in Iowa by Trowbridge and Williams from the Minnesota line to Dubuque. In the correlation of these various patches of the lower plain and in assigning their origin to peneplaination, the following facts are taken into consideration:

(1) The plain has numerous erosional remnants above it, for wherever the remnants of the upper plain occur in the form of mounds or ridges they rise above the lower plain surface, in most places as much as 200 feet or even more.

(2) This plain is in no way influenced by the strata of resistant rock, since it cuts across formations dipping at varying angles, the slope of the plain being remarkably uniform. In the Baraboo district the flat at 1200 feet above sea level cuts across the Baraboo quartzite formation which has dips of 15° or more. In the adjacent area to the west at the same elevation, the plain lies upon Prairie du Chien dolomite. South of the Baraboo district, the plain next cuts across the Galena dolomite at Lancaster at an elevation of 1100 feet, and finally in the Elizabeth quadrangle it is found upon five to fifteen feet of soft Maquoketa shale. In Iowa the plain cuts from the Prairie du Chien formation at the Minnesota line, across the St. Peter, Platteville, Decorah, and Galena formations, to the Maquoketa formation at Dubuque.

Over the area studied this plain dips at the rate of about four feet per mile in a direction 26° west of south. Thus it is seen that it dips at an angle smaller than that of the upper plain; accordingly the two plains draw more nearly together as they are projected to the southwest. Moreover, both plains have angles of dip which are less than the dip of the underlying strata, and they rise stratigraphically. For the relation of this plain to the underlying formations and to the upper plain in Wisconsin and Illinois, see figure 11.

(3) In spite of minor folds and dips, the plain is uniform. In the southern part of the Elizabeth quadrangle where the strata dip southwestward at an exceptionally high angle, the general level of the plain conforms to the level over the rest of the area, even though it is here on soft Maquoketa shale.

(4) Wherever found the lower plain is characteristically uniform and free from stream dissection except around the borders of its remnants. Especially is this noticeable when compared with the dissected character of the upper plain. This is the topography which a younger plain should have in contrast with that of an older one.

(5) The correlation made in the present paper departs from that of Grant and Burchard who consider that there is in the Lancaster-Mineral Point district an upper plain represented by the tops of the numerous mounds and that all the lower flat areas, including the Dodgeville Prairie, the flat around Lancaster, and the flat north of Cuba, belong to the lower or Lancaster plain. That this is in error is shown by a study of the elevations of this supposed plain. As shown by figure 12, the drop from Mt. Ida,

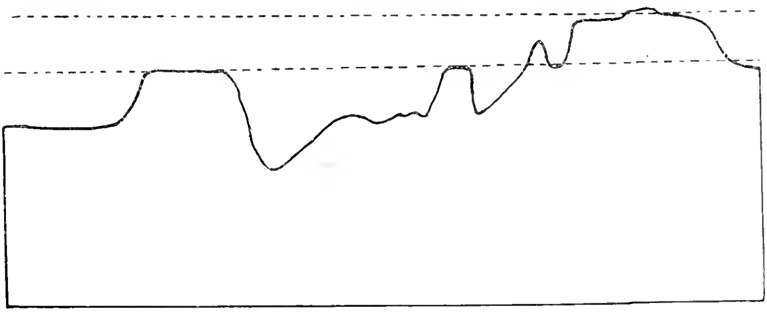

FIG. 12—A profile from Mt. Ida on the Dodgeville Prairie south across a portion of the Lancaster plain. Grant and Burchard assumed that the two upland surfaces shown here belonged to the lower or Lancaster plain. The profile makes it clear that two plains are represented.

a distance of only eight miles, is one hundred feet, or more than ten feet to the mile. Such a relation would be a severe strain on the idea of peneplaination. In characteristic topography, as well as in altitude, the Dodgeville Prairie belongs with the upper rather than with the lower plain.

AGE OF THE PLAINS.

The question of the age of the two plains is not relevant to the purpose of this discussion and only brief mention is here made of the two sets of interpretations which have been advanced. The earlier workers and some of the later ones consider the upper plain to be of Cretaceous age and the lower one to be Tertiary. On the other hand Salisbury has called the upper plain Tertiary, on the basis of a tentative correlation of the gravels on the plain with the Lafayette formation of the gulf coast. Work by Trowbridge and Williams in Iowa has placed the lower plain tentatively as early Pleistocene in age.

SUMMARY.

(1) There are two and only two upland plains in the region.

(2) Both plains are old peneplains.

(3) Both plains slope in a direction south by southwest and converge toward the south and southwest.

(4) The dip of the plains is less than that of the underlying strata and they cut across the bevelled edges of dipping strata, rising stratigraphically to the south.

(5) The upper plain shows more evidence of stream erosion than the lower.

(6) The Dodgeville plain belongs to the upper plain and the Lancaster plain of Grant and Burchard is a part of the lower plain.

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SUPERIMPOSITION OF KANSAN DRIFT ON SUB-AFTONIAN DRIFT IN EASTERN IOWA.

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Many new exposures have been made by the Chicago, Milwaukee and St. Paul Railway in the reconstruction of their line across Iowa. Various ones of these have proved to be of especial interest to Pleistocene geologists, and among them are several cuts in the northern part of Clinton county, showing superimposition of the two oldest drifts, the Kansan drift on the Sub-Aftonian drift. This paper is devoted to a description of these and their interpretation.

1. A significant exposure is located at the second viaduct one-half mile east of Delmar Junction. The cut is through a divide with a rounded summit, 250 to 300 yards long, and has a maximum depth of sixty feet. By reference to figure 13, A, the relations of the following materials will be clear:

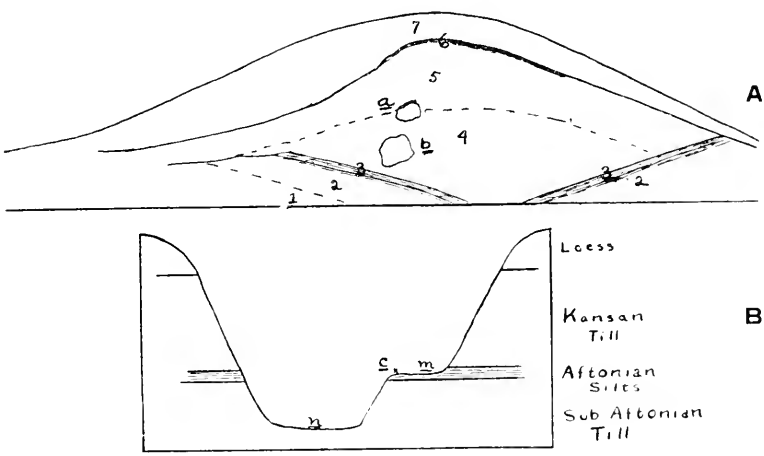

FIG. 13 A—Diagrammatic sketch of the relations of the materials shown in the south side of the Chicago, Milwaukee and St. Paul railway cut, one-half mile east of Delmar Junction.

FIG. 13 B—Cross-section of the railway cut referred to in A, showing the former track-level, *m*; the position of the mineralized stump, *c*; and the present track-level, *n*.

		Feet
Loess	7. Loess, 1 ft. of soil at top, grading below into brownish yellow to buff loess, wholly leached of calcareous material, mantles the eroded surface of the Kansan drift; thickness at the summit......................	8-10
Kansan Drift	6. Ferretto zone at the top of the till, absent from the slopes, reddish brown, leached, pebbles show considerable decomposition; thickness	0-1½
	Grades downward into:	
	5. Till, brownish yellow to yellow, summit rounded, leached of calcareous matrix and limestone pebbles in uppermost 7 to 8 ft., calcareous below with lime concretions and limestone pebbles, insoluble drift pebbles present throughout, lime concretions most abundant just below the base of the leached portion; maximum thickness.....	25
	Grades downward into:	
	4. Till, blue-gray or slate-colored, containing two large sand pockets, *a* and *b*, which have the appearance of included bodies, sand pocket *a* lies in the transition zone of (4) and (5), matrix of till calcareous and limestone and other drift pebbles present, fragments of wood in the basal portion, fills an old depression; thickness.........	0-28
Aftonian Soil	3. Old black soil, with many small fragments of wood mineralized with iron pyrite, pebbles rare, some imperfectly laminated clay, soil-zone delineates an old depression with slopes as high as 12°. At *c*, on an old track level (Fig. 13, B), is a stump with roots and rootlets running through the old soil and underlying clay; the wood is mineralized like the fragments of wood throughout the soil zone. Thickness of soil zone	2½-3
Sub-Aftonian Till	Grades downward into:	
	2. Till, dark bluish green on damp surface, light grayish green where dry, leached of calcareous matrix and limestone pebbles but other drift pebbles are present; thickness	6±
	Grades downward into:	
	1. Till, yellowish to brownish green, with some maroon-colored material in the lower part, leached 2-4 ft., calcareous below; thickness exposed	0-14

Interpretation.—This exposure seems to show quite clearly two distinct tills. The dark bluish green color of the till below the old soil zone is the color of material which has undergone deoxidation from a former oxidized state. Its transition below into material of yellowish to brownish color, with a greenish tinge, and the presence of carbonaceous material directly above, indicates that it was once oxidized but has been subsequently deoxidized, probably since the soil material has been deprived of atmospheric oxygen. The leaching of the lower till to a depth of about eight feet requires an interval of time, much longer than post-Wisconsin time, during which oxidation would likely have taken place. Directly above the soil zone is till which has never been leached or oxidized. These relations show quite clearly that the deposition of the two tills was separated by an interval worthy of the designation of an interglacial epoch.

The upper till-body is unquestionably Kansan. The topography of the surrounding region is not only erosional, like the Kansan area, but the upper till is weathered similar to the till of the Kansan area, both from the standpoint of degree and depth of oxidation and from the standpoint of depth of leaching.

Hence, if the upper till is Kansan, the lower till must be sub-Aftonian, and the soil development and leaching and oxidation of the lower till must be Aftonian in age.

The age of the stump just at the old track-level was carefully considered. Upon examination of various parts of the stump and its roots, it was found that the wood is mineralized with iron pyrite just like fragments of wood which are scattered throughout the Aftonian soil-zone. This evidence led to the conclusion that the stump belongs to the Aftonian soil and was uncovered in the excavation of the cut. This attention has been given to the stump, not because it necessarily adds to the weight of evidence for the differentiation of the two till-bodies, but it is the first stump, having an interglacial position, known to have been reported.

The position of the loess above the ferretto of the Kansan drift and as a mantle on the eroded surface of the Kansan drift, warrants the usual interpretation that a considerable interval of erosion and weathering intervened between the deposition of the Kansan drift and that of the loess about the Iowan drift border.

2. Another important cut is just west of the depot at Delmar Junction, on the north side of the tracks. This cut has a maximum depth of about twenty feet, is one hundred yards long and its summit is round. The materials exposed are as follows (figure 14, A):

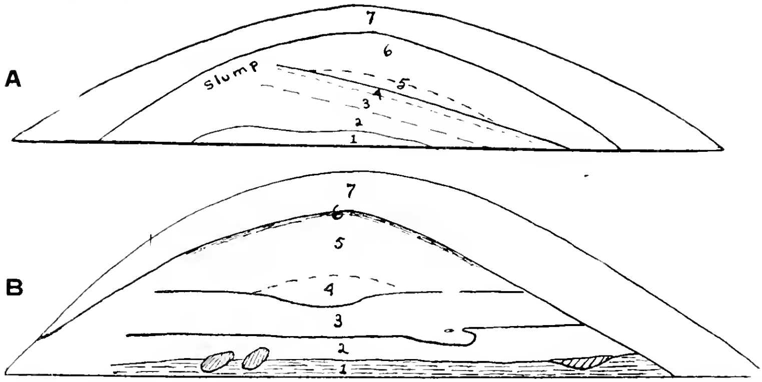

FIG. 14 A—Diagram of relations of materials in the north face of the Chicago, Milwaukee and St. Paul railway cut, just west of the depot at Delmar Junction, Clinton county.

FIG. 14 B—Diagram of the relations of the materials in the north face of the Chicago, Milwaukee and St. Paul railway cut, six miles east of Delmar Junction, Clinton county.

		Feet
Loess	7. Sandy loess, buff, well stratified, leached, thin soil zone at the top, conforms to the rounded summit of the underlying materials; maximum thickness................	10-12
Kansan Till	6. Till, brownish yellow to yellow, calcareous matrix, limestone pebbles present together with other drift pebbles up to the base of the loess where there is a concentration of pebbles; maximum thickness.............	8±
	5. Till, blue-black, containing some wood, line of oxidation above quite sharp, probably due to organic material, but *calcareous* like the above; thickness................	1-3
Aftonian Silts	4. Silts, dark brown, laminated, appear to have much carbonaceous substance, *leached*; thickness	1-1½
	Grades downward into:	
	3. Silts, gray, laminated, leached..............	3
Sub-Aftonian Till	2. Till, brownish yellow to yellow, with maroon streaks and some lamination, pebbles and cobbles up to 6 in. in diameter, leached 4½ ft. in one place, calcareous and limestone pebbles present elsewhere up to the base of the gray silts, some decayed pebbles; thickness, maximum.............	8±
	1. Till, bluish drab, calcareous; thickness......	0-3

Pebble counts from the unleached portions of both tills yielded the following results:

Kind	Kansan Till Per Cent	Sub-Aftonian Till Per Cent
Greenstone and Dolerite	46	42
Limestone	30	28
Granite	8	6
Chert	4	8
Quartzite	6	6
Schist	4	2
Quartz	2	2
Volcanic Porphyry	0	6
	100	100

Interpretation:—In this exposure, which is one-half mile from the former, the existence of the non-calcareous silts, containing carbonaceous material, between the calcareous till above and the leached and calcareous till below, makes it obvious that here there are also two till-bodies of different age. Inasmuch as this general region is one of mature erosion, as mentioned in the former case, the upper till is believed to be Kansan till, the silts Aftonian, and the lower till sub-Aftonian. The relations of the loess to the Kansan till in this cut do not clearly show an interval between their dates of deposition, but in view of the relations in the cut first described and of the mantling nature of the loess, it is probable that the rate of leaching of the Kansan till was at least equaled by erosion and consequently no leached zone remains. The lithology of the two tills, according to the pebble count, does not show any marked difference.

3. Farther east, about six miles east of Delmar Junction and one mile northeast of Riggs, a Chicago, Milwaukee and St. Paul Railway cut, trending north 30° east, fifty to sixty feet deep, and two hundred yards long, exposes two bodies of till, separated by a body of gravel. By referring to figure 14, B, the relations of the materials, which are described below, will be clear.

	Feet
7. Loess, soil-layer at the top 1 ft. thick, brownish yellow and non-calcareous down to the till, snail shells only in the calcareous portion; maximum thickness	30±
6. Ferretto zone of till, reddish brown, absent on lower slopes	0-1½

5.	Till, brownish yellow to yellow, leached 6 feet, calcareous and limestone pebbles below, upper horizon conforms to the contour of the hill and mantled by the loess, maximum thickness.......	20
	Grades downward into:	
4.	Till, gray-blue, calcareous, occurs below thickest part of the oxidized till and in a small depression of the underlying gravel; maximum thickness	8
3.	Sand and gravel body, extends across the cut except where mantled on the slopes by loess; limestone and other drift pebbles present, yellowish to brownish in color, lens and pocket-structure; thickness	10-12
2.	Till, light drab to dark drab at the top, brownish gray to dark gray below, dense and compact, limestone pebbles to the top, mostly decayed in the upper one foot, contains some inclusions of the underlying silt; thickness..................	12-14
1.	Silt, somewhat sandy, yet compact, dark gray, no pebbles, fragments of wood or roots of wood 1 to 2 inches in diameter exposed near the bottom, upper horizon somewhat undulating and in places shows gouging by an over-riding ice-sheet; thickness	12±

Interpretation:—There is no zone of leaching and oxidation within the drift materials which warrants a separation into two distinct tills. It has been thought, however, in view of the other exposures, that possibly the gravel-body represents such an interval as the Aftonian and that the overlying drift is Kansan in age and the underlying is sub-Aftonian. In this case, the bottom silt formation would be probably pre-Pleistocene. These determinations, however, must remain somewhat conjectural.

It is quite clear, however, that the loess formation was deposited on the Kansan drift after the latter had been eroded and weathered to its present state. This means a relatively long interval between the deposition of the two as compared with post-Wisconsin time.

SUMMARY OF THE CHIEF POINTS.

1. These exposures definitely record the invasion of the sub-Aftonian ice-sheet into the extreme eastern part of Iowa. Taking into consideration the other known exposures of sub-Afton-

ian drift in Iowa and Nebraska, it appears that in a broad way the sub-Aftonian and Kansan ice-sheets covered approximately the same territory from east to west, a territory much more extensive than was covered by any of the later ice-sheets in the Keewatin field.

2. Where the sub-Aftonian drift is definitely differentiated from the Kansan drift, the sub-Aftonian shows a leached zone considerably deeper than that of the Wisconsin drift. On this basis the length of the Aftonian interval was considerably greater than post-Wisconsin time. This is in harmony with the evidence of the Aftonian mammalian fossils that the interval was long and warm, and when both evidences are considered it is to be inferred that the ice-sheet was melted back at least to its present limits.

3. The existence of the two oldest drifts in this locality and the absence of any evidence that the Maquoketa and Wapsipinicon river valleys below Monticello and Anamosa, have been occupied by an ice-sheet, indicate that these superimposed valleys have been carved since the Kansan ice invaded this region.

4. The Kansan drift was weathered and eroded to its present state before the loess in this locality was deposited, hence this weathering records an interval much longer than post-Wisconsin time. The weathering and erosion of the Kansan drift does not, therefore, represent its age. The loess itself shows three to four times the leaching that the Wisconsin drift shows, and the length of time represented must be added to that shown by the weathering and erosion of the Kansan drift, in order to fully appreciate the great age of the Kansan drift.

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A NOTE ON FULGURITES FROM SPARTA, WISCONSIN.

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During the summer of 1915 some fulgurites were found near Sparta, Wisconsin, in a small sand knoll composed of residual quartz grains of the Potsdam formation, which is Upper Cambrian in age. The sand is fairly clean and of uniform character and is being reworked continually by the wind since there is only a scant covering of vegetation.

The fulgurites consist of irregular, thin-walled tubes of fused siliceous sand grains. The tubes vary in length and diameter. The smallest are about one-eighth inch long while the largest are several inches in length. The pieces may be the fragments of one large tube, the smaller pieces being the branches from the main stem. The surfaces of the fulgurites are very irregular and are traversed by deep furrows with minor undulations. The entire surface is covered with the grains of sand which came in contact with the fused material. Some of the grains are white and opaque, due to complete fusion, while others are brown and have remained unaltered. The interior of the fulgurites is smooth, highly glazed glass and the surfaces correspond to the furrowed surfaces of the outer walls in outline. The deviations of the tubes from a circular form are due probably to the pressure of the adjacent sand while the fulgurites were still in a fused condition.

Fulgurites are caused by lightning striking in sand and fusing the siliceous sand grains into a tubular form.

A NEW STRATIGRAPHIC HORIZON IN THE CAMBRIAN SYSTEM OF WISCONSIN.

W. D. SHIPTON.

During the summer of 1915 it was the privilege of the writer to work on the geology of the Sparta quadrangle, Wisconsin. In connection with that work a new stratigraphic horizon in the Cambrian was recognized.

The normal section of the Cambrian in Wisconsin[1] is as follows:

		Thickness in Feet
3.	Madison sandstone	35- 50
2.	Mendota limestone	30- 45
1.	Potsdam Proper sandstone	800-1000

In the Sparta quadrangle, the Mendota member is missing, and a new Cambrian member is recognizable. Because of its wide distribution and excelllent exposures around Sparta, this persistent, shaly member has been named by the writer the Sparta member. Its base lies 290 feet and its surface about 90 feet below the top of the Cambrian: that is, the member is approximately 200 feet thick and includes the upper 165 feet of the Dresbach member (Potsdam Proper) and the whole of the Mendota member in the normal section for the state. In the Sparta quadrangle the Cambrian is divided into the following members:

		Thickness in Feet
3.	Madison sandstone	90
2.	Sparta shale	200
1.	Dresbach sandstone	820-879

Many exposures of the Sparta beds are to be found throughout the region. Two type localities are a quarry two miles southeast of Sparta in the southwest corner of section 30, township 17 north, range 3 west, and a quarry one and one-half miles north of Sparta in the center of section 1, township 17 north, range 4 west. From the latter quarry good exposures may be seen by visiting the series of quarries along the upland to the northeast. The beds are well exposed along the road and

[1] Irving, Roland D., Geology of Wisconsin, Vol. II, p. 460.

in a gully one-half mile north of Middle Ridge in the northwest corner of section 2, township 15 north, range 5 west. Another good exposure occurs along the road in Pine Hollow two and one-half miles southeast of Melvina in the northwestern corner of section 19, township 15 north, range 3 west.

The beds of the Sparta member consist of argillaceous layers of sandstone alternating with thin, fissile, arenaceous and calcareous layers, all with more than fifty per cent sand. The arenaceous beds are mostly thin, but a few reach two feet in thickness; the more limy layers are rarely more than one inch thick. The layers apparently become more calcareous near the Madison-Sparta contact. The fissile shales vary in color. Some of the beds are of green glauconitic color, due to disseminated grains of glauconite. Other beds which contain minute glistening micalike scales and small black particles grade from a light gray to a dark gray color. Where the beds are mainly glauconite a greenish color is imparted to the soil. The layers are distinctly laminated and break into thin plates. The laminæ in most places are horizontal; in many places a minor cross-bedding is visible. The rocks tend to split along the laminæ, which are formed apparently of the green grains of glauconite, the diminutive micalike specks, and the minute dark particles. Some fragments of calcite are found. The most shaly beds are nicely ripple-marked, the markings being asymmetrical. A type locality for the ripple-marked layers is two miles northwest of Sparta, along the Big Creek road in the eastern part of section 9, township 17 north, range 4 west.

The Sparta beds are used for quarrying purposes; the member is called "Free Rock" owing to its being quarried so easily, the term being of strictly local application.

This peculiar phase of the Potsdam, here called the Sparta shale, appears not to have been given a distinct stratigraphic horizon previously. Chamberlin[2] notes a stratum of shales attaining a known thickness of 80 feet somewhat above the middle of the Potsdam formation. Above the shale is 150 feet of sandstone which is overlain by 35 feet of shale and limestone (the Mendota limestone). In the Sparta region the shale stratum reaches a total thickness of 200 feet and is overlain by the Madison sandstone; the Mendota apparently is missing. This may

[2]Geology of Wisconsin, Vol. I, pp. 121-122.

be a local modification as noted by Chamberlin.[3] The Sparta beds differ from the Mendota limestone in several respects, as follows:

1. The maximum thickness of the Mendota at the type locality at Madison is thirty-five feet[4] while the maximum known thickness is eighty feet.[5] The Sparta beds reach a maximum thickness of two hundred feet.

2. The Mendota member has been recognized as a limestone or a calcareous horizon[6] in the upper part of the Potsdam, and, as such, should effervesce upon the application of acid. No such action takes place when the acid is applied to the Sparta beds, although there are minor concentrations of calcium carbonate which would undoubtedly respond to acid. An analysis of the Mendota limestone given by Irving[7] bears a close similarity to the Prairie du Chien (Lower Magnesian) formation. This analysis shows a high percentage of lime carbonate. As stated above, the Sparta member contains more than fifty per cent sand.

3. The Mendota beds have been considered as a horizon for trilobites,[8] and where typically exposed numerous trilobite remains have been found. Although many exposures of the Sparta beds were examined carefully, no trace of trilobite remains was found. The presence of certain species of brachiopods belonging to the Lingula group[9] also characterizes the Mendota horizon. The fauna of the Sparta beds includes an uncertain species of Obolella and the impressions of a doubtful Orthis. Faunally, there is a difference between the Mendota and the Sparta beds.

The Sparta beds do not seem to be the equivalent of the Saint Lawrence member since Calvin[10] recognized the Saint Lawrence member as evenly bedded calcareous strata corresponding to the fifth trilobite bed of Owen and attaining a thickness of thirty-five feet.

In a recent publication of the Wisconsin Geological and Natural History Survey,[11] the Upper Cambrian is subdivided into

[3]Geology of Wisconsin, Vol. I, pp. 121-122.
[4]Bull. XIII, Wis. Geol. and Nat. Hist. Surv., p. 92.
[5]Geology of Wisconsin, Vol. II, p. 259.
[6]Bull. VIII, Wis. Geol. and Nat. Hist. Surv., p. 37.
[7]Geology of Wisconsin, Vol. II, pp. 543-544.
[8]Geology of Wisconsin, Vol. II, p. 261.
[9]Geology of Wisconsin, Vol. II, p. 261.
[10]Iowa Geol. Survey, Vol. IV, p. 59.
[11]Bull. XXXV, Wisconsin Geol. and Nat. Hist. Survey, pp. 30-31.

six formations by Ulrich, one of which is the Franconia. It is possible that the Sparta beds may be the equivalent of the Francenia formation, but since no description of the Franconia beds has been published, it is impossible to make a definite statement to this effect. The topographic position of the Franconia appears to correspond with that of the Sparta member.

Winchell[12] recognized the Saint Lawrence and associated shaly beds as having a total thickness of 200 feet. These beds are probably the equivalent of the Sparta member.

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[12] Final Rept. of the Geol. and Nat. Hist. Survey of Minnesota, Vol. II, p. XXII.

THE LOESS OF CROWLEY'S RIDGE, ARKANSAS.

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Crowley's Ridge is a narrow, more or less interrupted elevation which extends from southeastern Missouri to Helena, Arkansas.[1] Its slopes, especially on the eastern side, are frequently quite abrupt (see Plate V, figure 1), and it forms a striking topographic feature of this part of the Mississippi valley.

It has received some notice from geologists. Owen refers to it in both the First (1858) and Second (1860) Arkansas Reports; and Call has given the most complete account of its geology,[2] including a chapter by Salisbury; and Chamberlin included a discussion of it in his paper on the Interval between the Glacial Epochs.[3]

The loess of the southern part of this ridge presents certain interesting features, and it has received some previous attention, especially from Call. Some years ago (1907) the writer visited the southern part of Crowley's Ridge and made some studies of the loess, the results of which have not been published because it was planned to extend the observations along the entire ridge. As this has not yet been possible, the report on the southern portion of the ridge is here presented.

Two distinct sections of the ridge were studied. The first is a detached portion about seventeen miles long, which extends from Helena to Marianna, and is cut off from the main ridge to the north by the valley of the L'Anguille river. The second is that part of the ridge extending from the L'Anguille valley to Forrest City and Madison.

The finest exposures were found in Helena, along the eastern slope of Crowley's Ridge, particularly that part lying west of Poplar street, between Louisiana and Walker streets. Three of these exposures are figured on Plate V, figure 2; Plate VA, figure 1, and Plate VB, figure 2.

[1]It is mapped in the Arkansas Geological Reports, Vol. II, 1891.
[2]Geol. Survey of Arkansas, Vol. II, 1891.
[3]Bulletin of the Geological Society of America, Vol. I, 1890, pp. 469-80.

The section shown in Plate V, figure 2, is located north of Elm street, facing Poplar street. It shows the following members:

a—Reddish loess, about 2 feet.
b—Whitish loess, 25 to 30 feet.
c—A chocolate-colored band, in some places appearing like old soil.
d—A mucky reddish clay.
e—Contains more or less gravel.

The maximum height of the exposure is about seventy-five feet.

The reddish loess follows the contour of the hill on the side of the exposure beyond (a), which faces to the right, and it is nearly uniform in thickness, and contains no fossils. The white loess here contains only fragments of shells. The member (d) is evidently Call's lower "loess", but it is not loess.

The lines of demarcation between the several members are not always sharp, but the several divisions stand out quite distinctly.

The cut figured on Plate VA, figure 1, is located north of Elm street, facing Poplar street. It shows the following members:

a—Reddish loess, variable in thickness but sometimes forming nearly one-third of the section. Stands vertically in the banks. It is fossiliferous.
b—A transition band between reddish and white loess. Variable in thickness.
c—White loess, very fossiliferous, partly obscured by the talus.

The same members occur in the exposures near Forrest City. Plate VB, figure 2, shows a section southwest of Madison, east of Forrest City:

a—Reddish loess, about 4 or 5 feet; no fossils.
b—White loess, 2 to 3 feet; with fragments of fossils. The dark line running through (b) is an oxidized band.
c—A gravelly layer, sharply separated from (b).

The division into an upper reddish and a lower whitish loess is almost everywhere quite pronounced. The two loesses are in some places quite sharply separated, but usually there is a narrow transition band, ordinarily only a few inches thick.

The upper loess differs from the lower not only in being reddish in color, but also in texture and other characters. It is grittier, more inclined to stand vertically in the exposures, and it sometimes shows a fine lamination which follows the contours of the hills more or less distinctly. It sometimes contains nodules, and it is often fossiliferous.

The lower loess is whitish, often somewhat putty-like, finer, and less inclined to scale off from vertical banks. It usually contains some calcareous nodules, sometimes iron streaks and bands, and often many fossils. It is sometimes yellowish, especially just below the reddish loess, and it then often shows whitish lines evidently formed by rootlets.

Sometimes short bands of broken shells appear in the white loess, especially where the upper part of the loess is very fossiliferous. Such a band is illustrated on Plate VB, figure 2. These bands are usually a foot or more in length, and are evidently formed in vertical cavities which have been formed by water following crevices. Such cavities are often gradually filled with material from the upper part of the stratum, and if that part is fossiliferous shells are sometimes washed down and deposited in a layer on the bottom of such a cavity. The subsequent filling of the cavity completes the imbedding of the shell layer. Such a cavity is shown at (d) on Plate VB, figure 1, and a shell band (the one which is figured on the same plate, figure 2) is set off by markers at (c).

In most of the exposures which were examined there is a more or less distinct brownish band just below the lower loess, and where this is the case the lower limit of the loess is sharply defined. Sometimes this dark band is wanting, and then it is not always easy to determine the lower limit of the loess, especially if the underlying layer is of the same color as the whitish loess, as sometimes occurs. It is evident that Call regarded this layer below the white loess as "typical" loess, one of the two forms of loess which he recognized, though he observes that it is not fossiliferous. It is probable that Salisbury regarded this as a lower loess[5], and Chamberlin was also inclined to so regard it[6], but added that "it remains with us an open question whether this belongs to the glacial series or not."

Its texture, its grading into gravelly deposits, and its lack of fossils clearly show that it is not loess. The presence of calcareous nodules (on which Call placed some reliance) in both the white loess and the underlying stratum proves nothing as to identity or close relationship, for such nodules are formed not only in loess, but also in drift (especially when modified), etc. There

[4]Ibid., p. 171.
[5]Ibid., p. XV.
[6]Bulletin of the Geological Society of America, Vol. I, 1890, p. 476.

are two loesses on Crowley's Ridge, but they are not the two described in former reports. The differences between them in color and texture are probably due to variations in the source of dust supply during the period of formation, possibly to shifting of river courses.

The inclusion of the lower stratum as loess led Call to exaggerate the thickness of the loess at Helena. It is much less than ninety feet in thickness.

The fossils.—Both the true loesses of the ridge contain shells, frequently in large numbers. Both, or either one, may be fossiliferous in the same section, or both may be without fossils. All the fossils (with the exception of *Planorbis (Gyraulus) deflectus*, reported by Call as rare, but which the writer failed to find) are terrestrial. Even the operculate *Pomatiopsis lapidaria*, which Call reported as aquatic, is strictly terrestrial so far as the writer has ever observed. In this respect, therefore, the fauna of this loess is typical.

However, it presents certain very interesting variations. The difference between the fossils of the red and white loesses at Helena, as shown in the appended table of fossils, is not very great, but the red loess shows a smaller number of species, and its fauna taken in the aggregate is rather less typically southern than that of the white loess. When we compare the fauna of the Helena loess with that of the Forrest City region, however, we find a greater difference, and the latter is clearly northerly in its affinities. It is evident that the valley of the L'Anguille river formed a barrier which was not passed by several southerly species.

A comparison of the Helena loess fauna with that of Natchez, Mississippi[7], shows that they are very similar, only three of the Natchez species (*Polygyra inflecta*, *Vitrea hammonis*, and *Cochlicopa lubrica*) being absent at Helena, though found at Forrest City. Eight of the Helena species are not found at Natchez.

The following list of fossils from Crowley's Ridge adds sixteen species to the lists published by Call. The figures indicate the number of specimens collected. Those marked + were reported by Call.

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[7]See the following for the Natchez list: American Geologist, Vol. XXX, 1902, p. 290; and Bulletins from the Laboratories of Natural History, State University of Iowa, Vol. V, 1904, p. 310.

LOESS FOSSILS FROM CROWLEY'S RIDGE.

	Helena		Madison
	White Loess	Red Loess	White Loess
Polygyra albolabris (Say) Pils	31	...	...
Polygyra thyroides (Say) Pils	3	...	+
Polygyra exoleta (Binn.) Pils	+	...	...
Polygyra elevata (Say) Pils	35	...	...
Polygyra multilineata (Say) Pils	3	35	1
Polygyra profunda (Say) Pils	98	107	1
Polygyra appressa (Say) Pils	142	76	...
Polygyra palliata (Say) Pils	+	...	+
Polygyra fraudulenta Pils	4	...	1
Polygyra obstricta (Say) Pils	2	...	...
Polygyra inflecta (Say) Pils	...	...	+
Polygyra stenotrema (Fer.) Pils	19	...	..
Polygyra hirsuta (Say) Pils	199	346	10
Polygyra monodon (Rack.) Pils	2	...	...
Polygyra monodon fraterna (Say) Pils.	115	34	...
Strobilops labyrinthica (Say) Pils	+	...	...
Bifidaria contracta (Say) St	62	...	+
Bifidaria pentodon (Say) St	51	...	...
Bifidaria corticaria (Say) St	11	...	...
Vertigo gouldi (Binn.) Stimp	+	...	...
Vertigo ovata Say	86	...	...
Cochlicopa lubrica (Muell.) Fer	+	...	4
Circinaria concava (Say) Pils	25	31	1
Omphalina kopnodes (Binn.) Pils	3	5	...
Vitrea hammonis (Strom.) Pils	...	...	4
Vitrea indentata (Say) Pils	80	101	2
Vitrea placentula (Shuttl.) Pils	143	171	...
Vitrea capsella (Gld.) Pils	10	...	...
Euconulus fulvus (Drap.) Reinh	52	2	2
Zonitoides arboreus (Say) Pils	40	18	2
Zonitoides minusculus (Binn.) Pils	84	10	2
Gastrodonta ligera (Say) Pils	25	86	...
Pyramidula solitaria (Say) Pils	6	...	...
Pyramidula alternata (Say) Pils	118	52	+
Pyramidula alternata (*var.*)	13	...	...
Pyramidula perspectiva (Sáy) Pils	1	...	1
Pyramidula cronkheitei (Newa.) Pils	43	33	13
Helicodiscus parallelus (Say)	200	45	8
Punctum pygmaeum (Drap.) Binn	696	...	...
Sphyradium edentulum (Drap.) St	20	...	...
Succinea ovalis Say	30	29	2
Succinea avara Say	3	16	4
Carychium exile H. C. Lea	2	...	...
Planorbis deflectus Say	+	...	...
Helicina orbiculata tropica (Jan.) Pfr	9	...	...
Pomatiopsis lapidaria (Say) Try	70	1	32

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EXPLANATION OF PLATES.

Plate V, Fig. 1.—A portion of the east side of Crowley's Ridge at Helena, Arkansas.

Fig. 2.—Cut on the south side of Porter street, west of 1st street, Helena.

a—Red loess, 2 feet.

b—White fossiliferous loess, 25 to 30 feet.

c—Dark colored band at base of loess.

d—Red mucky clay.

e—A gravelly stratum.

Plate V A, Fig. 1.—Cut facing Poplar street, north of Elm street, Helena, Arkansas.

a—Red loess, variable in thickness. Fossiliferous.

b—Transition band between the two loesses.

c—White loess, very fossiliferous.

Fig. 2.—Cut southwest of Madison, Arkansas.

a—Red loess. 4-5 feet.

b—White loess, 2-3 feet; with fragments of fossils.

c—A gravelly layer.

Plate V B, Fig. 1.—A cut west of Poplar street, and facing St. Mary's street, Helena, Arkansas.

a—White loess.

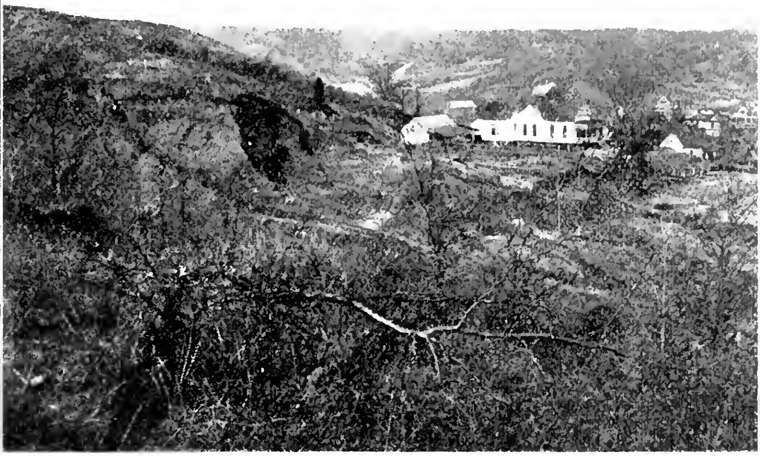
b—Heavier clay.

c—Shell band.

d—Cavity in which shell band may form.

Fig. 2.—A shell band between two markers. Same section as in fig. 1.

1



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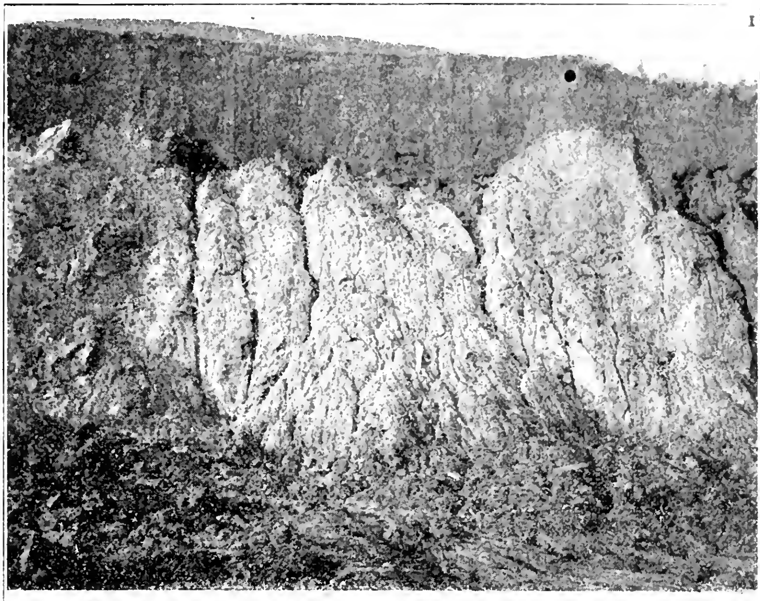
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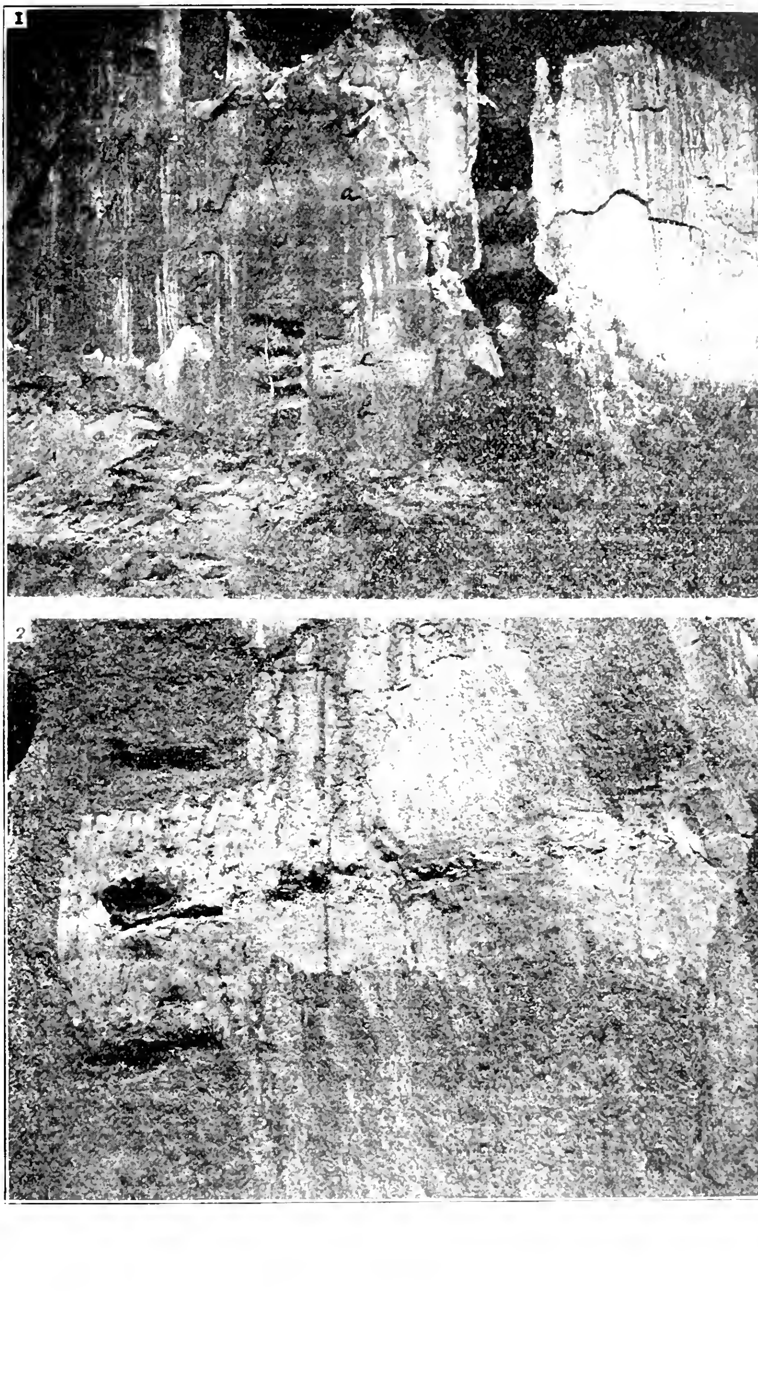
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BIBLIOGRAPHY OF THE LOESS.

E. J. CABLE.

Bain, H. F., Geology of Plymouth County, Iowa: Iowa Geol. Survey, Vol. 8, 1897, p. 318.

Bain, H. F., Geology of Carroll County, Iowa: Iowa Geol. Survey, Vol. 9, 1898, p. 51.

Beyer, S. W., Loess: Iowa Geol. Survey, Vol. 7, 1896, p. 197.

Broadhead, G. C., Origin of Loess: Am. Jour. Sci., third series, Vol. 18, 1879, p. 447.

Call, R. E., Loess in Central Iowa: Am. Naturalist, Vol. 15, 1881, p. 782.

Chamberlin, T. C., and *Salisbury, R. D.*, The Driftless Area of Upper Mississippi Valley, U. S. G. S. Sixth Ann. Rept., 1885, p. 199.

Hayden, F. V., Upland Loess of Missouri; its formation: Am. Geologist, Vol. 25, 1900, p. 369.

Hayden, F. V., An. Report of U. S. G. S. of Territories, 1867, pp. 10, 12, 18, 19.

Hayden, F. V., U. S. G. S. of Wyoming and Contiguous Territories, 1870, p. 98.

Hershey, O. H., Loess Formation of the Mississippi River: Science, N. S., Vol. 5, 1897, p. 768.

Huntington, E., Chart of The Distribution of Loess: Bull. Geol. Soc. America, Vol. 25, 1914, p. 575.

Huntington, E., Loess Deposit of Kuen Lun Mountain: Bull. Geol. Soc. America, Vol. 17, p. 351.

Keyes, C. R., Eolian Origin of Loess: Am. Jour. Sci., Vol. 6, 1898, pp. 299-304.

Leverett, F., Significance of the White Clays of the Ohio region: Am. Geologist, Vol. 10, 1892, p. 18.

Leverett, F., The Illinois Glacial Lobe: Monograph U. S. Geol. Survey, Vol. 38, 1899, p. 156.

Leverett, F., To the Manner of Distribution: Am. Geologist, Vol 33, 1904, p. 205.

Leverett, F., Post-Sangamon or Main Loess and Associated Silts: Monograph U. S. Geol. Survey, Vol. 53, pp. 74-76.

Leverett, F., The Loess: Monograph U. S. Geol. Survey, Vol. 38. Beneath Wisconsin drift, p. 187-188.

Aeolian origin, pp. 183-184.

Analyses of, pp. 158-164.

Discussion of, p. 32.

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Mode of deposition, 176-184.

Relation to gummy clay, p. 31.

Leonard, A. G., Geology of Dallas County, Iowa: Iowa Geol. Survey, Vol. 8, 1897, p. 51.

Mabry, T., The Brown or Yellow Loam of Northern Mississippi, and its relation to the Northern Drift: Jour. of Geology, Vol. 6, 1898, p. 273.

McGee, W J, Pleistocene History of Northeastern Iowa: U. S. G. S. Eleventh Ann. Rept., Vol. 10, 1892, p. 18.

Norton, W. H., Iowa Geol. Survey, Vol. 9, 1898, pp. 404, 484, 485.

Obrucheff, M., Origin of Loess: Geographic Journal, Vol. 42, p. 403.

Owen, Luella A., Evidences on Deposition: Am. Geologist, Vol. 35, 1905, p. 291.

Pumpelly, Raphael, Loess in Central Asia: Bull. Geol. Soc. America, Vol. 19, p. 243.

Pumpelly, R., Fresh Water Lake Deposits: Am. Jour. Sci., Vol. 6.

Pumpelly, R., The Loess of the Mississippi Valley and the Eolian Hypothesis: Am. Jour. Sci., third series, Vol. 18, 1879, pp. 133-144.

Pumpelly, R., Loess in Central Asia; Formation of: Bull. Geol. Soc. America, Vol. 17, p. 643.

Sardeson, F. W., What is the loess: Am. Jour. Sci., 4th ser., Vol. 7, 1899, p. 58-60.

Salisbury, R. D., Loess of Western Illinois and Southeastern Iowa: Journal of Geology, Vol. 4, p. 244.

Salisbury, R. D., Loess in Wisconsin Drift Formation: Journal of Geology, Vol. 4, p. 929.

Safford, J. M., Geology of Tennessee, 1869, pp. 114, 433, 434.

Shimek, B., Additional Observations on the Surface Deposit of Iowa: Proc. Iowa Acad. Sci., Vol. 4. 1896, p. 68.

Shimek, B., The Distribution of Loess Fossils: Jour. of Geology, Vol. 7, p. 122.

Shimek, B., The Nebraska Loess Man: Bull. Geol. Soc. America, Vol. 19, p. 243.

Shimek, B., Eolian Loess. Origin: Science, N. S., Vol. 33, 1911.

Shimek, B., Loess of Gildner Mound: Bull. Geol. Soc. America, Vol. 19, pp. 250-255.

Shimek, B., Loess of Peczel, Hungary, Proc. Iowa Acad. Sci., Vol. 22, 1915, p. 285.

Shimek, B., The Genesis of Loess, A Problem in Plant Ecology: Proc. Iowa Acad. Sci., Vol. 15, 1908, p. 57.

Shimek, B., Living Plants as Geological Factors: Proc. Iowa Acad. Sci., Vol. 10. 1903. p. 41.

Shimek, B., The Loess: Bulletins Natural History State University of Iowa, Vol. 5, pp. 341, 359, 360.

Shimek, B., The Loess of the Missouri River: Proc. Iowa Acad. Sci., Vol. 14, 1906, p. 237.

Shimek, B., Mississippi Loess at Natchez: Am. Geologist, Vol. 30, 1902, p. 279.

Shimek, B., The Loess of Crowley's Ridge, Arkansas: Proc. Iowa Acad. Sci., Vol. 23, 1916.

Shimek, B., Aqueous Origin Criticism: Am. Geologist, Vol. 35, 1905, p. 291.

Shimek, B., The Theory of Loess.: Proc. Iowa Acad. Sci., Vol. 3, 1895, p. 82.

Shaw, E. W., Origin of the Loess of Southwestern Indiana: Science, N. S., Vol. 41, pp. 104-108.

Todd, J. E., The Degradation of Loess: Proc. Iowa Acad. Sci., Vol. 5, 1897, p. 46.

Todd, J. E., Annual Deposits of the Missouri River during the Post-Pliocene: Proc. Am. Association for the Advancement of Sci., Vol. 26, 1877, p. 287.

Todd, J. E., The Moraines of Southeastern South Dakota and the attendant deposits: Bull. U. S. Geol. Survey No. 158, 1899.

Todd, J. E., Pleistocene Problems in America: Bull. Geol. Soc. America, Vol. 5, p. 351.

Udden, J. A., Horizontal Shearing Planes: Jour. Geology, Vol. 10, p. 245.

Udden, J. A., The Mechanical Analysis of Loess: Bull. Geol. Soc. America, Vol. 25, 1914, p. 728.

Udden, J. A., Iowa Geol. Survey, Vol. 11, 1900, p. 258.

Wright, G. F., Agency of Water in Deposition: Am. Geologist, Vol. 33, 1904, p. 205.

Wright, G. F., The Great Ice Age, p. 359.

Wright, F., Origin and Distribution of Loess in Northern China: Bull. Geol. Soc. Am., Vol. 13, p. 127.

White, C. A., Iowa Geol. Survey, Vol. 1, 1870, p. 531.

Wilder, F. A., Iowa Geol. Survey, Vol. 10, 1899, p. 81.

Wilcox, O. W., On certain aspects of the Loess of Southern Iowa: Jour. of Geology, Vol. 12, p. 716.

Winchell, N. H., Aqueous Origin of Loess: Bull. Geol. Soc. America, Vol. 14, pp. 141-143.

Witter, F. M., Observations on the Loess in and about Muscatine, Iowa: Ia. Acad. of Sci. Proc., 1877-89, p. 45.

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THE LITHOGENESIS OF THE SEDIMENTS.

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There are few lines of investigation in geology which promise more fruitful returns than the lithogenesis of the sediments. The sedimentary rocks have from the first been sadly neglected although the igneous and metamorphic groups have been systematically and more or less intensively studied both in the field and in the laboratory. Even the megascopic characters of the sediments have for the most part been indefinitely and vaguely described and petrographic examinations have until recently rarely been made. Descriptive terms have been indiscriminately used and such important features as mud cracks and many others equally as significant have in many cases been wholly overlooked. Moreover, until within the last ten years few serious attempts were made to determine the conditions of deposition of the clastic sediments. It is little wonder then that the application of more refined methods of study to these rocks bids fair to revolutionize the fields of physical stratigraphy and paleogeography.

The importance of careful study of recent sedimentary deposits of both the continental and marine types as a basis for interpreting the history of the ancient sediments cannot be too strongly emphasized, as was pointed out recently by both Andrée[1] and Goldman.[2] Indeed some of the greatest contributions to stratigraphy have come through such studies. The importance of Drew's recent investigation on the deposition of limestone through the agency of bacteria in the modern seas[3] as bearing on the origin of the ancient thick, fine-grained limestones which in themselves furnish no positive clue as to their mode of formation must be admitted by all.

Witness also the valuable contributions of Grabau and Barrell, who, working independently, have been able not only to prove beyond a reasonable doubt that many of the thick Paleozoic clastic formations of the Appalachian region which were formerly believed by all to be either of marine or estuarine origin

[1]Petermann's Mitteilungen Vol. 59, part 2, 1913, p. 117 ff.
[2]Am. Jour. Sci., 4th ser., Vol. 39, p. 287.
[3]Carnegie Inst. Washington, Pub. 182, 1914, pp. 9-45.

really represent great continental delta fans, but also to outline the probable climatic conditions which existed at the time they were formed by comparing them with similar recent and near recent deposits of known origin.

Studies such as those made by Sherzer[4], who found upon examining recent sand grains formed by various agencies that each type possessed characteristics to a certain degree of its own, also promise to be of great value in deciphering the history of the ancient sediments. For instance there are strong reasons for suspecting that certain sandstone formations made up of sand grains possessing all the characteristics of recent wind blown sand are of eolion origin, or at least consist of eolion sands reworked by the sea as it transgressed upon the land.

Similarly Walther and Huntington and others by their descriptions of the characteristics of modern desert deposits have contributed valuable data which already have been applied in interpreting the history of the sediments of the past. Thus, wind carved pebbles similar in every way to those described by Walther and others from the Libyan desert have been found, according to Grabau[5] "in the pre-Cambric Torridon sandstone of Scotland, the basal Cambric sands of Sweden, the Rothliegende of Germany, the Buntersandstein of Thuringia and elsewhere" thereby suggesting strongly the existence of desert conditions at the time these beds were formed. In like manner a type of cross-bedding shown by Walther to be characteristic of the modern sand dunes of the deserts of Egypt, and observed by Huntington in Persia, Transcaspia and Chinese Turkestan has been observed by Huntington[6] in certain Mesozoic sandstones of Utah and by Grabau and Sherzer in the Sylvania sandstone of Silurian age, of Michigan[7].

But in spite of the great advancement of physical stratigraphy within recent years resulting from the field study of sediments, we may expect even greater advances in the future, especially as the result of more detailed examination of the sediments with the aid of the microscope. Here lies a great field almost untouched, although its possibilities have been shown by the studies of Sorby, Cayeux, Mackie, G. S. Rogers, Gold-

[4]Bull. Geol. Soc. America, Vol. 21, 1910, pp. 625-662.
[5]Principles of Stratigraphy, p. 54.
[6]Bull. Geol. Soc. America, Vol. 18, 1907, p. 351.
[7]Mich. Geol. and Biol. Survey, Pub. 2, Geol. Series 1, 1910, p. 61 ff.

man and others. There can be no doubt that the additional evidence furnished by petrographic study as to the composition and structure of the ancient sediments will aid greatly in interpreting the conditions of their deposition as well as the nature of their source. Sorby[8] showed the possibilities in this line several years ago, by his petrographic examination of clays and shales. He found the structure of these to differ greatly, a fact which argues for their formation under very different conditions. That such characteristics are fairly constant for any given formation is suggested by the experience of Denckmann who found that a widely distributed Silurian formation of Silesia possessed distinct petrographic peculiarities by means of which he was able to identify it at those localities where fossils were either rare or entirely wanting[9]. It seems certain that to some extent at least, the nature and constitution of the sediments of any given formation are directly related to the climatic conditions which existed during deposition as well as to the source from which they were derived. If then we may determine in what way climatic changes are registered in the sediments by converging all lines of evidence we shall be able to decipher more accurately by means of the microscope the climates of the past as well as the nature of the ancient lands. Some steps have already been taken in this direction by Mackie[10] who has suggested that the kinds and degree of freshness of the feldspar grains in sandstones may be used as a key in determining the climatic conditions under which the sandstones were formed, and who has demonstrated also that the nature of the parent rock is indicated by the kinds of minerals present and by the nature of their inclusions.

It is believed that studies of this type will go a long way toward solving the problem of the origin of certain little understood formations such as the red beds and the Coal Measures in addition to furnishing more accurate data regarding the geography of the past. When all these things are better known we shall have the basis also for a much more complete classification of the sedimentary rocks than the one which we now possess.

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[8]Quart. Jour. Geol. Soc. Vol. 64, 1908, pp. 171-233.
[9]Cited by Andrée, Geol. Rund., Vol. 2, 1911, p. 61.
[10]Trans. Geol. Soc. Edinburgh, Vol. 7, pp. 443-468.

THE WESTERN INTERIOR GEOSYNCLINE AND ITS BEARING ON THE ORIGIN AND DISTRIBUTION OF THE COAL MEASURES.

FRANCIS M. VAN TUYL.

(ABSTRACT.)

Late studies of the Mississippian formations of southeastern Iowa for the Iowa Geological Survey have shown that these formations were tilted to the southwestward and partly truncated in late Mississippian time. There is convincing evidence that this tilting was related to deformation over a wide area in southern Iowa, southeastern Nebraska, eastern Kansas and northwestern Missouri which outlined a southwestwardly pitching geosyncline in which the Coal Measures of the Western Interior coal field were deposited. This geosyncline was shallow in early Pennsylvanian time and probably did not greatly exceed 700 feet in depth at the close of the Cherokee stage. At the present time, however, it is approximately 2400 feet deep at the deepest known point which is at McFarland, Kansas. An important part of the deepening is believed to have been brought about by subsidence during the post-Cherokee stages of the Pennsylvanian.

The magnitude and significance of the basin has been demonstrated by the construction of 100 foot contours on the base of the Coal Measures from data furnished by the reports of the State Geological Surveys of Iowa, Missouri and Kansas.

The presence of this basin not only explains the great dissimilarity between the Coal Measures of this field and those of the Eastern Interior field which were undoubtedly deposited in a distinct basin, but also explains the belted arrangement of the outcrops of the Pennsylvanian formations, particularly in Iowa, Missouri and Kansas, where the younger members are approximately confined to the center of the basin, progressively older ones being exposed towards its margins. The present distribution has resulted from post-Paleozoic erosion of the dipping beds but there are reasons for believing that the Missouri formations were never as extensive as those of the Des Moines and that the younger members of the Missouri itself were more restricted than the older ones.

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THE PLEISTOCENE OF CAPITOL HILL.

JAMES H. LEES.

The Pleistocene exposures on Capitol Hill at Des Moines have become classic through the studies made by McGee and Call which demonstrated the presence of glacial drift overlying loess. The results of these studies were published in the American Journal of Science, Volume 24, 1882, pp. 202-223.

Recent extension of the Capitol grounds has necessitated extensive grading on the south part of Capitol Hill. This has revealed the strata to considerable depths and made possible more complete examination of the Pleistocene deposits than McGee and Call could make. The grading thus far has been done on East Court avenue between 10th and 12th streets and so includes the localities of McGee's sections 3 and 4. For the sake of comparison these sections are here reproduced verbatim.

SECTION 3.

N. side Court Av. bet. E. 10th and E. 11th Sts.—Alt. 880± 3 ft.

1. Light reddish-buff unstratified drift clay containing numerous rounded, subangular and angular pebbles, mainly erratic, up to six inches in diameter, bits of coal and a lenticular mass of Carboniferous clay three feet long, and six inches thick. Seven feet.

2. The same, obscurely and irregularly stratified, interstratified with bands of loess, and sometimes contorted, containing loess-kindchen, tubelets and fossils (often fragmentary), in the drift strata in direct association with pebbles, as well as in the bands of loess. Five feet.

3. Loess, similar to and continuous with that observed in sections 1 and 2, abounding in loess-kindchen, tubelets and fossils.

SECTION 4.

S. side Court Av. bet. E. 10th and E. 11th Sts.—Alt. 882± 3 ft.

1. Reddish-yellow sandy clay containing numerous rounded, subangular and angular pebbles up to twelve inches in diameter, associated toward the base with loess-kindchen and fossils. About eight feet.

2. Loess, light buff, somewhat sandy and pebbly above, containing numerous loess-kindchen, tubelets and fossils. Six feet.

The formations above the loess, as described by McGee, are not visible at present, as they have been in part concealed, in part removed, by later building operations. However, on the south side of Court avenue, between 10th and 11th streets the following section is revealed and must lie below McGee's section:

1. Loess, yellow with gray spots and streaks and masses, especially where rootlets have penetrated. Ferruginous "pipe stems" are quite numerous in the gray portions of the loess. No fossils were seen in the lower three or four feet, but above this zone they are quite abundant, in places to the top of the exposure. No kindchen were seen in this exposure. The lower foot of the body of loess grades down from yellow to reddish brown with gray streaks. In one place a four inch band of finely jointed reddish clay with starchy structure lies four inches from the base of the loess. It contains some small sandstone pebbles and extends along the face for a few feet. Apparently the loess is all one body. The great mass, with the exceptions noted, is uniform from top to bottom in color, texture and general appearance. Fifteen feet from level of 11th street.
2. Geest, residual from Coal Measures shale; reddish brown, sticky clay containing small pebbles of sandstone and shale. Contact with loess above sharp, no gradation. One foot near 11th street, thicker near 10th street, where cover is thin.
3. Coal Measures shales, red, purple, blue, green, one to three feet; succeeded by solid bed of light blue shale, with a two inch band of black shale six feet below the top. Exposed fifteen feet to grade at 10th street.

The upper surface of the geest is practically horizontal, while the ground surface slopes to the west toward the Des Moines valley bottoms. Hence the loess thickens from a thin veneer at 10th street to fifteen feet at 11th street. A number of years ago an excavation above the level of 11th street revealed about six feet of gray loess with "pipe stems" and concretions. Still farther back from the present exposure the surface rises about ten feet and probably the loess here is overlain by drift.

Another section on the south side of Court avenue midway between 11th and 12th streets is representative of the material along this part of the cut:

1. Till, weathered, brownish. About three feet.
2. Till, buff, pebbly. About five feet, grading into No. 1.
3. Till, gray, pebbly, grading into buff above. Four feet.
4. Till, gray, alternating with sand streaks. Two feet.
5. Loess, gray and buff, banded, abundant shells, lower surface sloping to east. One to two feet.
6. Clay, buff, somewhat sandy in places, abundant pebbles, for most part rather small, some up to two inches, elsewhere six to eight inches in diameter. Pebbles are fresh limestones, quartzes, greenstones, and granites, some of which are badly disintegrated. Shells of loess types also are abundant in this clay in places, while in others they are rare or absent. Between this member and No. 5 are rolled masses of gray loess with concentric lamination well developed. Two to three feet.
7. Clay, brown, jointed, loess shells abundant, no pebbles, probably a weathered loess. One and one-half feet.
8. Loess, gray, shells abundant. One foot.
9. Loess, buff, fossiliferous. Three feet.
10. Loess, gray, fossiliferous. One foot.
11. Sand, in lens extending 100 feet along Court avenue; here two feet thick, at its maximum, fifty feet west, six feet thick. The sand is fine, yellow with brown streaks, and presents masses of coarser, reddened material near the top. It is strongly cross-bedded. The lens dips slightly toward the northeast, in which direction it thins to about two feet, but attains a length of over 150 feet.
12. Loess, gray for about one foot, then grading down into buff. Shells are abundant and of the usual loess types. At several localities along the line of this section there are shown masses of dark blue loess which is rather harder than the buff variety. Fossils are abundant here also. These masses are enclosed by the buff loess and some of them are as much as five feet in height and ten to twelve feet long. This blue loess does not seem to be distinct from the buff loess in anything except color and doubtless is occupying its original position. Exposed in gas main trench ten feet. Shales were not reached at this locality.

The lower body of loess, No. 12, is continuous with the loess of the first section given, but it rises about ten feet higher in the first section, as there apparently it was undisturbed by the overriding glacier and by glacial waters.

It is evident from its situation that the gray loess is an alteration product from the buff loess. It is found uniformly above the buff loess, and both above and below the sand lens, where water percolation is more easy than elsewhere, the loess assumes the gray color. Loess kindchen and "pipe stems" are found in the gray loess, not in the original buff type. Wherever the loess is more than a very few feet thick it is buff with depth. It is clear that the gray loess is not to be interpreted as a distinct deposit and the same may be affirmed of the dark blue masses found in the yellow loess.

These exposures, together with numerous others between Des Moines and Keokuk, seem to indicate that the gray loess so common in the lower Des Moines valley may have been changed from a buff original, one similar to the loess of the Missouri valley except for the absence of kindchen in the Des Moines yellow loess and their abundance in the Missouri valley deposit.

The pebbly fossiliferous clay, number 6 of the above section, is to be considered, perhaps, as in part a result of the washing by waters from the Wisconsin ice of the loess with its contained fossils, and the mingling of this with clay, sand and gravel from the till. No doubt it is partly the result also of the eroding, mixing work of the ice itself. In character and general appearance it is intermediate between till and loess. In places it is gray, and appears as if composed of mingled gray, unoxidized Wisconsin till and gray loess. It is very common and its general relations are well shown just east of 11th street along the north face of the cut. Here are exposed in horizontal succession: drift, pebbly, yellow above and gray below, twenty-five feet; grading into shell-bearing pebbly gray clay, fifteen feet; replaced abruptly, but with no *line* of division, by loess, grayish above, yellow below, thirty feet; succeeded again by fossiliferous, yellow pebbly clay, twenty feet exposed. Under all of these lies the sand lens, two to three feet thick, and under this in turn is gray loess. A few feet of yellow or brownish Wisconsin till forms the surface material along all of this exposure, which is about twenty feet in height.

To show the extreme variability in materials within short distances the following section from the intersection of 12th street and Court avenue is added. This is not over two hundred feet from the second section given. Below the level of 12th street the following succession was shown:

1. Fill and altered drift, yellow, in places with a thin line of calcareous nodules at the base. Two feet.
2. Drift, yellow, pebbly. Two feet.
3. Silt, brownish, no fossils. Two feet.
4. Silt, red, no fossils. Two feet.
5. Clay, buff, bearing both pebbles and fossils. Five feet. Laterally this gives way without a break to alternating gray and buff loess, with many fossils and a few concretions, which here is four feet thick. Below it is exposed one foot of dark blue fossiliferous loess. At the contact there were found several iron-coated limestone pebbles two inches long. Two feet above the base of the buff loess was found a chert pebble two inches long, and at several points both the blue and buff loess show layers and pockets of sand, about six inches thick and several square feet in area. Pieces of wood are quite common in loess of both colors.

A few feet from the above section a mass of Carboniferous shale was shown in the wall. It was twenty feet long by three feet thick and was underlain by typical gray, pebbly Wisconsin till while above it lay altered till which contained lime concretions.

While the great sand lens described in the second section is overlain by loess on the south side of the cutting, on the north side it lies directly beneath modified drift and loess which evidently have been disturbed. It seems probable that it represents an immense sand bowlder which was forced into its present position by the ice. The contorted character of some of the coarser parts tends to bear out this theory.

Aside from showing the presence of a young drift on the loess these exposures reveal unusually well the work of the glacier at the extreme limit of its advance. The intermingling of the drift and the loess with its fragile shells, many of which are still entire; the variation of materials within small intervals of space; and the presence of a great lens of sand lying on the body of loess—all these are features which show how gentle and yet how irresistible was the action of the ice.

The stages of alteration of the Wisconsin drift were well shown in several localities. The second section described is quite typical. The thinness of the drift in this general region is to be expected, but the fact that it changes from unaltered gray through buff to brownish within ten feet or less shows how brief, relatively, has been the period during which this sheet of till has been exposed to the elements.

It will be noted that there is in the first section no trace of a drift beneath the loess. All of this had been swept away and the Coal Measures shales leveled off and a layer of geest formed before the loess was deposited. The cuts indicate also that the Wisconsin drift in turn was spread out on a mature topography developed on the older surface.

IOWA GEOLOGICAL SURVEY,
DES MOINES.

A HIGHLY ALATE SPECIMEN OF *ATRYPA RETICULARIS* (LINN.)

A. O. THOMAS.

The most abundant fossil in the upper part of the Wapsipinicon beds at Independence and elsewhere in east central Iowa is a fine-ribbed representative of *Atrypa reticularis* (Linn.).[1] This species is found in every fossiliferous horizon in the Devonian of the state. Indeed, it is world wide in its distribution and is the "longest lived of all known organisms,"[2] ranging from early Silurian through the Devonian into the early Mississippian.[3] Generally speaking, however, the species came to an abrupt end with Devonian time although the genus continued on for a brief period into the Mississippian.[4] In a species ranging so widely both vertically and geographically many varietal forms are usually developed. In the Devonian of Iowa nearly every horizon that may be set off at all sharply by lithological or faunal differences has its peculiar variety or mutation of *A. reticularis* which in some cases perhaps could be well designated as good species. Such a variety is the fine-ribbed, rather robust form from Independence which has "a tendency to become alate at the cardino-lateral angles, and having a form that is decidedly lenticular, particularly in the young and half grown individuals."[5] In rare cases the curious marginal alations or fringes are preserved.

Specimens illustrating marginal alations were obtained by the late Professor Calvin from a quarry in the suburbs of Independence many years ago. The quarry which furnished the best specimens has long since fallen into disuse so that good examples are now obtained with difficulty.

The alations or winglike expansions are made up of a number of thin lamellæ which extend from the surface of the valves.

[1]Iowa Geol. Surv., vol. viii, 1898, p. 229.
[2]Clarke and Swartz, Maryland Geol. Surv., Upper Dev., 1913, p. 586.
[3]Herrick: Bull. Sci. Lab. Denison Univ., vol. iii, 1887, p. 98, pl. iii, fig. 11; vol. iv, 1888, pl. ix, fig. 7.
[4]For example, *Atrypa infrequens* Weller. Ill. Geol. Surv., Monog. I, 1914, p. 285, pl, xxxv, figs. 1-5, Glen Park limestone (Kinderhook), Glen Park, Missouri.
[5]Calvin; Amer. Geol., vol. 8, 1891, p. 143.

arising from what are generally regarded as lines of growth on the ordinary Atrypa shell. These concentric lines, however, are rather more than records of halts in the growth of the shell, in appearance they approach varices where the plications are slightly dilated and elevated as may be seen on shells from which the lamellæ are removed. Each lamella extends outward in such a way as to make a small angle with that part of the shell proper which continues beyond the line of their common union. The successive lamellæ lie more or less closely one upon another near their bases but out toward their margins they are considerably separated and the spaces between them are filled with the ordinary matrix in which the shells are preserved. There is no evidence that the lamellæ ever coalesced. Their surfaces partake of the characteristic markings of the shell itself and the plications or ribs on the lamellar surfaces are continuations of those on the shell; with growth the plications increase in size, bifurcate, and so on, as do those which continue over the shell. The lamellar surface is wrinkled and uneven in contrast with the smooth evenly rounded surface of the valves. As seen in section the lamellæ vary in thickness and the outer and inner surfaces of each lamella are similarly plicated, that is, each lamella is a rigid corrugated layer. The plications on one lamella do not coincide either in size or always in direction of growth with those on the surfaces of adjacent lamellæ immediately above or below.

The alation is developed in a plane roughly parallel to a plane passed between the valves; its lateral development along the posterior margin gives the shell the appearance of having a long straight hinge-line; anteriorly the lamellæ bend to conform to the sinuosity of the front margins of the valves.

The hardness of the rock in which the Iowa specimens occur and the fragility of the lamellæ make it difficult to disengage a complete specimen. The one here figured is so broken along the margin that the full size is not known. Even fragmentary preservation is rare; the shells showing alations in the collection at hand as well as those seen in the field are usually mature and old individuals,—more frequently the latter, since "those [lamellæ] upon the umbonal and median surfaces of the valves, have been worn off during the life, or before the fossilization of the shell."[6]

[6]Hall and Clarke; Pal., N. Y., vol. viii, pt. ii, p. 168, Albany, 1894.

This feature on *A. reticularis* was pointed out and illustrated sixty years ago by the Sandberger brothers on a specimen from the Rhenish Devonian of Germany.[7] Davidson[8] described and illustrated some interesting examples of *A. reticularis* with "foliated expansions" from the Wenlock limestone, Silurian, of England. Whiteaves[9] figured a specimen from the Devonian of Canada. His figure illustrates the lamellæ remarkably well. Its greatest width is 14 millimeters more than that of the specimen here illustrated from Independence. Clarke and Swartz[10] discuss this feature on specimens of this species from the Devonian of Maryland. Other references could easily be added but these will suffice to show that this feature is not limited to the Atrypas of any given locality. Moreover, it seems to have been a characteristic of *A. reticularis* at various times throughout its history and doubtless was developed to a greater or less extent on several of its many varieties. What the purpose of these excrescences could have been we can only conjecture. Such seemingly useless and extravagant skeletal matter in many cases presages racial old age and final extinction but their presence on members of the species in the Silurian soon after the species had made its appearance seems to preclude this explanation. It is quite possible that short lived offshoots of the species, destined to disappear, developed these encumbrances during their later stages.

The alate specimen which is the subject of this article has a maximum width of 10 cm. and a length of 6.5 cm.; the "hinge-line" is 7.3 cm. long. The lamellæ which are preserved are all outgrowths of the pedicle (ventral) valve, those formerly on the brachial (dorsal) valve having been almost wholly broken away; the width of the alation on the specimen averages three centimeters.

Specimens from the same bed, on which the alations are not preserved, show the usual expression of the species. The non-lamellate specimens illustrated in the accompanying plate are quite similar to those described and illustrated from the same bed by James Hall in 1858.[11]

[7] Die Verstein. d. Rhein. Schicht. in Nassau, pl. xxxiii, fig. 1, Weisbaden, 1856.

[8] British Sil. Brach., pp. 129-133, pl. xiv, figs. 1, 2. London, 1867.

[9] Contr. Can. Pal., vol. I, pt. iv, p. 289, pl. xxxvii, fig. 8; Ottawa, 1892.

[10] Maryland Geol. Surv., Upper Dev., p. 586, pl. lv, figs. 6, 10; Baltimore, 1913.

[11] Hall's Geol. of Iowa, vol. I, pt. ii, p. 515, pl. vi, figs. 1, 5.

Occurrence: Calvin's "*Spirifer pennatus*" beds, uppermost part of the Wapsipinicon stage (Fayette breccia), Devonian; near Independence, Iowa.

Specimens in the paleontological collections of the University of Iowa.

GEOLOGICAL LABORATORIES
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EXPLANATION OF PLATE V C.

Atrypa reticularis (Linnæus).

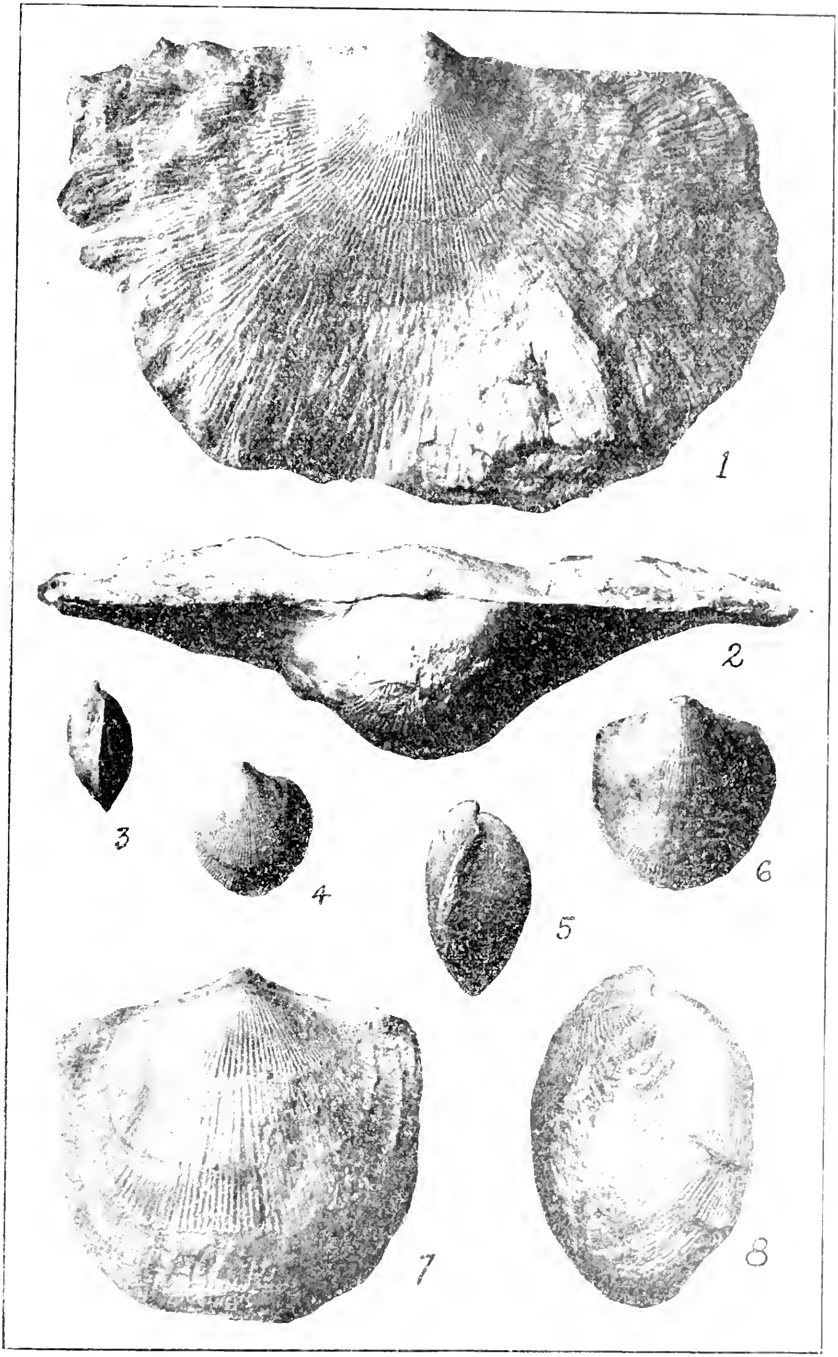
Figure 1. Pedicle view showing the strong development of the marginal lamellæ. Note the fine ribs on the shell and the wrinkling of the lamellar surface.
No. 600, x $\frac{1}{1}$

Figure 2. Same specimen. Posterior view.

Figures 3, 4. Lateral and pedicle views of a young specimen showing the fine ribs and the "decidedly lenticular" form mentioned by Calvin. No. 601, x $\frac{1}{1}$

Figures 5, 6. Lateral and brachial views of a nearly mature example showing the initiation of greater convexity in the brachial valve. Note the rather weakly developed varices on this and the preceding.
No. 602, x $\frac{1}{1}$

Figures 7, 8. Brachial and lateral views of an old individual. Note the strong sub-equally spaced varices from which the lamellæ have been broken off.
No. 603, x $\frac{1}{1}$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ON THE VARIATION IN THE REFLECTING POWER OF ISOLATED CRYSTALS OF SELENIUM AND OF TELLURIUM WITH A VARIATION IN THE AZIMUTH OF THE INCIDENT PLANE POLARIZED LIGHT.

L. P. SIEG.

The reflecting power of a surface is defined as the ratio of the intensity of the light reflected at perpendicular incidence to the intensity of the incident light. There are two ways of determining the reflecting power of a metallic surface. One is by a direct, or photometric (dioptric) method. The other is by an indirect (katoptric) method. In the latter an analysis is made of the elliptically polarized light coming from the surface in question, upon which plane polarized light is incident. This analysis yields what are called the optical constants of the substance. These constants are the index of refraction, the absorption index, and the reflecting power. Both methods have been used repeatedly and the concordance of the results gives us such faith in the indirect method, that, in view of the fact that the absorption index and index of refraction of the metal constituting the surface are much more easily determined by the second method, we generally employ this indirect method. Nevertheless it is always desirable when possible to check the results by some direct experimental attack.

Most of the work done on metallic surfaces has been done, not only by the indirect method, but also on rather large polished surfaces of the metals in question. In view of the fact that metals are essentially crystalline, it becomes at once an open question as to whether the optical constants determined from large polished surfaces represent the real facts. For unless the crystals constituting the metal belong to the cubic system, one should certainly expect a set of optical constants depending on the orientation of the crystalline axis. In this view, then, the constants ordinarily determined can represent only, except in the case of metals of the cubic system, certain mean values of the actual constants.

With this view in mind, some two years ago, the writer set one of his students, Mr. C. H. Skinner, at work to determine the optical constants by a katoptric method of an isolated crystal of selenium. Although selenium is not regarded as a metal, it has, nevertheless, optically speaking, many qualities of a metal. The crystals are optically very dense and offer brilliant reflecting surfaces. Skinner succeeded in proving definitely that there were distinct differences in the optical constants, depending upon whether the long axis of the hexagonal crystal was vertical or horizontal. This work is not yet published in full, but an abstract has recently appeared[1]. Some years ago Drude[2] and Müller[3] worked on isolated crystals of antimony sulphide, and proved that from one cleavage plane, (0 1 0) two distinct sets of optical constants were obtained. Other work has been done, notably by G. Horn[4], on the absorption of certain crystals, but the writer is not aware that any work on *elemental* metallic crystals with the exception of a determination of the absorption of bismuth and antimony by the latter author, has been done. The reason for this is not far to seek, for usually the crystals of metals are microscopic in size. The difficulty in working with such small surfaces by the ordinary methods led the writer to suggest this task of obtaining a special method to another of his students, L. D. Weld. The latter has succeeded admirably in this problem, and a preliminary report of the work is presented to the Academy of Science at this meeting.

Aside from the importance of crystals in yielding us the true constants of various substances, there is good reason for believing that the crystalline surface should be better adapted for the purpose than any artificially formed polished surface. If this is correct, then even the cubic crystals should be re-examined by this method. The one reliable trait of all crystals seems to be their maintaining of constant angles, and even if there seem to be striations on some of the surfaces, it may be that these irregularities would not seriously affect the optical constants. Then too where it is possible to obtain a fresh surface by cleavage, one should expect the most relia-

[1]C. H. Skinner, Phys. Rev. 7, 1916, 285.
[2]P. Drude, Ann d. Phys., 34, 1888. 489.
[3]E C. Müller, N. Yahrb. f. Miner. Beil. Bd., 17, 1903, 187.
[4]G. Horn, N. Yahrb. f. Miner. Beil. Bd., 12, 1899, 269.

ble results. Drude[5] and Müller[6] both found that a fresh surface of antimony sulphide deteriorated rapidly after coming into contact with the air.

The writer thought it to be highly desirable to determine the reflecting power of certain of these crystals by a direct method. If these results should show definitely a difference in the reflecting power with difference in azimuth of the incident plane polarized light, then there would be a larger amount of reliability to be placed in the results that are being obtained in this laboratory by the more exact, but indirect methods.

The plan of the experiments was very simple, but the execution has been rather difficult. The first arrangement was an apparatus by which plane polarized light from a monochromator, varying in wave length throughout the visible spectrum, could be thrown upon a linear thermopile, and secondly reflected upon this thermopile by reflection at nearly normal incidence from the crystalline surface. The ratio of the second deflection of the connected galvanometer to the first would give at once the reflecting power. By rotating the crystal in the plane of its surface through 90°, and repeating the above experiment, one could get the reflecting power from this azimuth. The results were, however, unsatisfactory because not enough energy could be obtained from the small crystalline areas to give reliable deflections of the galvanometer.

A second attempt was made in which a crystal of selenium, connected in a Wheatstone's bridge, was substituted for the thermopile. The effect of light on the selenium is to decrease its resistance, and it was thought in view of the fact that a selenium receiver is much more sensitive in the visible spectrum than the thermopile that definite results could be obtained. However, the crystal employed, although more sensitive than the thermopile, proved unfortunately to be more erratic and unsteady in its action. While perseverance would no doubt have led to a more satisfactory crystal receiver, it was decided for the time being to abandon this plan of attack and to use a spectrophotometric method. The apparatus was arranged in several different ways which need not be gone into here, before what proved to be a satisfactory method was found. The plan is shown in figure 15. Light from a Nernst glower, *G*

[5]P. Drude, loc. cit.
[6]E. C. Müller, loc. cit.

later a nitrogen filled tungsten lamp was employed placed in a light-tight box is focused by a lens, L_1 at the points N_1 and H. This division of the light was accomplished by means of a mirror M_1 partly intercepting the light. N_1 is a Nicol prism which can be set at any desired angle. Passing through N_1 the light meets the lens, L_2 and by it would be brought to a focus at H were it not for the crystal plate at X. This latter returns the light through the totally reflecting prism, P and it

Fig. 11.

is finally focused on the lower half of the slit of the monochromator I S E. The other portion of the original beam of light passes through L_3 to the mirror M_2, thence through the lens L_4, the Nicols N_2 and N_3, the latter with an attached circular scale and vernier, and lastly is focused by means of the lens L_5 upon the upper half of the slit of the monochromator. These two beams pass through the instrument and form on the emergent slit two images of the front slit, one above the other, and formed by light traveling along the two separate paths. The wave length [illegible] which [illegible] wishes to make an examination is obtained by setting the graduated screw S. The instrument had of course been calibrated. These two images are viewed through the eye-piece E. The procedure is to set S for a wave length at [illegible] of the visible spectrum, then to rotate the Nicol N_3 until the two images are matched in brightness. By proper adjustment of the mirror M_1, the light coming by the long path can always be made, with the Nicol in position, more intense than that by the shorter path, so that it can always be reduced in intensity for an intensity match.

Having run through the spectrum with the crystal X set, say with its long axis agreeing with the electric vector from the Nicol N_1, the latter is now turned through 90° and the operations are repeated. Then in order to make certain that the changed azimuth of the polarized light does not cause changes in intensity due to the mirrors and prisms rather than to a difference in the reflecting power of the crystal, two more settings are employed. The crystal is rotated through 90° and the electric vector from N_1 is first vertical and secondly horizontal. From these four sets of readings one is in a position to calculate the reflecting power of the crystal with two different azimuths of plane polarized light. The present work was not designed as an attack on the absolute reflecting power of the surfaces but merely to obtain the differences due to these two different azimuths of the incident light. In order to get absolute results one must know the area illuminated and then substitute for X a substance of the same area and of known reflecting power—silver for instance. This was done in the present case by using black glass and by carefully shielding to make certain that the light reflected from the silvered glass of mirror M_1 represented nearly constant reflecting power throughout the spectrum. This agrees with published results.[1]

In the near future it is planned to obtain the absolute reflecting power of these and of other crystals. Not the greatest confidence can be placed in the variation in the reflecting power through the spectrum, that is as to whether there are any small maxima or minima, for the uncertainties in matching intensities make absolute reliability in this regard only to be obtained through extremely long and careful experimentation. However, the fact of the variation in magnitude of the reflecting power with the azimuth of the incident plane polarized light stands out clearly, and this was the primary object of the research up to the present point.

The first crystal tried was a hexagonal crystal of selenium[2] made by sublimation in an atmosphere of hydrogen. The [illegible]

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[1] [illegible], Phys. Rev. [illegible]

[2] The writer is much indebted to Dr. F. C. Brown for [illegible] selenium and to Dr. [illegible]

shown in figure 16 represents typical results of these experiments. The method of using four settings was not adopted at the time these first experiments were performed, so although the differences in the reflecting power are genuine, there are undoubtedly corrections that should be made. It will be noticed that the reflecting power is practically constant throughout the spectrum. This is in a way substantiated by direct observation, for the light reflected from these brilliant surfaces is free from any observable trace of color. It will be noted that the

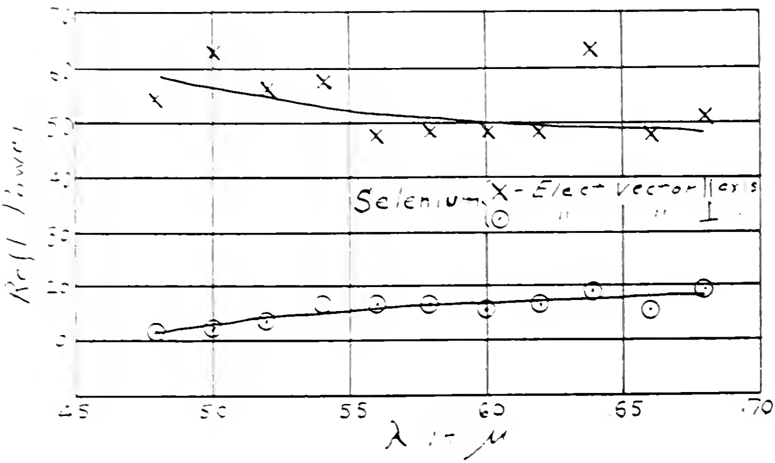

FIG. 16.

reflecting power is greatest when the electric vector is along the long axis of the crystal. This is in agreement with what we should expect, because it is along this axis that the elasticity is greatest. The intensities of the reflected light are taken as proportional to the square of the cosine of the angle through which the Nicol N_1 is turned from its position parallel to the Nicol N_2. The direct results here given corroborate the results obtained by the indirect method, and so no doubt add to the confidence in the latter.

The next crystal employed was one of tellurium, formed in Taylor gun. It is planned in this laboratory to make a careful study of the optical constants of this element, but up to the present time this work is not completed. It was thought, however, long enough to try these preliminary experiments on this crystal for future reference in the more extended work. The particular crystal used was a very long acicular hexagonal crystal, and was made by sublimation in an atmosphere of nitrogen by Mr. Tisdale of this laboratory. The details of the way in which this was done is described in this volume of the Proceedings, see page 209. The surface of the crystal was about 0.5 mm by 7.0 mm, and was one of the six similar sides of the hexagonal crystal. In these last experiments correction was made for the possibility of a variation of the intensity of the light passing through the monochromator and also for a variation in the area of the crystal illuminated when it was rotated through a right angle. The corrections were made as follows.

Let r_1=the intensity of the reflected light when the electric vector lies along the crystal's long axis.

r_2=the intensity of the reflected light when the electric vector is perpendicular to the crystal's long axis.

a_1=the reduction factor for the intensity due to the passage through the monochromator when the electric vector is vertical.

a_2=the reduction factor when the vector is horizontal.

b_1=the fraction of the crystal illuminated when the crystal is vertical.

b_2=the fraction illuminated when horizontal.

Then $r_1a_1b_1$, for example, will be the intensity as measured by experiment (square of cosine of the angle of rotation of N_2 for an intensity match) of the light reflected from the surface when both the vector and the crystal's long axis are vertical. The other combinations are readily interpreted.

Let $r_1a_1b_1=m$

$r_2a_2b_1=n$

$r_1a_2b_2=p$

$r_2a_1b_2=q$

Solving these we obtain

$$r_1 : r_2=(mp : nq)^{\frac{1}{2}} ; \quad a_1 : a_2=(mq : np)^{\frac{1}{2}} ; \quad b_1 : b_2=(mn : pq)^{\frac{1}{2}}$$

In the following table are listed the values of the square of the cosine of the angle of rotation of the Nicol, N_2, for the different wave lengths, and for the four positions stated above. It will be seen that the ratio of the two reflecting powers is, as in the case of selenium, practically a constant throughout the spectrum, the one with the electric vector along the long axis being greater than the one at right angles to this in the ratio of about 1.7 to 1. the values of b_1/b_2 should come out a constant. and the variation in the table is merely an indication of the experimental errors. The ratio a_1/a_2 would not necessarily be a constant, although it so proves to be within the errors of the experiment.

TELLURIUM.

Wave Length (micra)	m	p	q	n	a_1/a_2	b_1/b_2	r_1/r_2
.66	.48	.53	.36	.25	1.14	.78	1.68
.64	.48	.57	.38	.25	1.13	.74	1.70
.62	.50	.55	.35	.27	1.06	.84	1.71
.60	.50	.57	.38	.25	1.15	.76	1.73
.58	.50	.59	.40	31	1.05	.81	1.55
.56	.55	.59	.36	.30	1.06	.88	1.74
.54	.52	.59	.38	.27	1.11	.79	1.73
.52	.53	.57	.38	.27	1.14	.81	1.72
.50	.55	.57	.38	.28	1.15	.84	1.72
.48	.55	.53	.38	.28	1.19	.88	1.66

Conclusion.—The importance of a study of isolated crystals has been pointed out and preliminary direct results on the reflecting power of a selenium and of a tellurium crystal have been obtained. These results have supported the original contention, and are. the writer believes, the first direct results published for these two elements to show that they have different reflecting powers. Heretofore these reflecting powers have been determined from large polished mirrors of these elements, and of course only one value for each element for each wave length has been determined. Further work along this line is to be done in the immediate future.

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A PHYSICAL REPRESENTATION OF THE SUMMATION OF CERTAIN TYPES OF SERIES.

L. P. SIEG.

Most of us are on the lookout for concrete illustrations of abstract ideas. To be able to visualize a mathematical process is to many of us a step toward the better understanding of that process. The following brief discussion, although having no pretentions to absolute originality, is offered as a physical illustration of the summation of certain simple geometric series.

In the accompanying four diagrams of figure 17 we have a series of four sketches of combinations of simple machines. In each case a weightless platform supporting a man of weight W is suspended from the point a of the weightless, frictionless lever Fab. The fulcrum of this lever is at F. The point of application of the force f which the man exerts, in the manner shown by the arrow in each case, is at the point b. The force f is transmitted to the point b by the frictionless fixed pulleys P_1 and P_2 in diagrams *1* and *3*, and by the frictionless fixed pulley P_1 in diagrams *2* and *4*. The mechanical advantage of the lever is considered to be m, in order to make the problem general, where m is greater than unity in diagrams *1* and *2*, and less than unity in diagrams 3 and 4.

The problem in each case is to determine the force f that will place the system in equilibrium. This is of course a very simple physical problem. However, there are at least two ways of approaching the solution of the problems, and it is in the results from these two methods of approach that we find the ideas involved in this paper.

Consider diagram *1*. We can solve this problem algebraically by equating the weight of the man plus the reaction of the force f, which he exerts, to the upward force f multiplied by m, the mechanical advantage of the machine, Fab. This gives us

$$W + f = mf \qquad (1)$$

or

$$f = W/(m - 1) \qquad (2)$$

The second manner of attacking the problem is in an approach by an infinite series. The man can be considered as in readiness to exert the proper force, and he indulges in the following reasoning. First he knows that if his weight is W he must pull with a force of W/m in order to support himself. But this force will create an additional thrust on the platform of W/m, and so he must exert an added force of W/m^2 to overcome this. This added force in turn causes an extra thrust on the platform of W/m^2, and so he must exert an additional pull

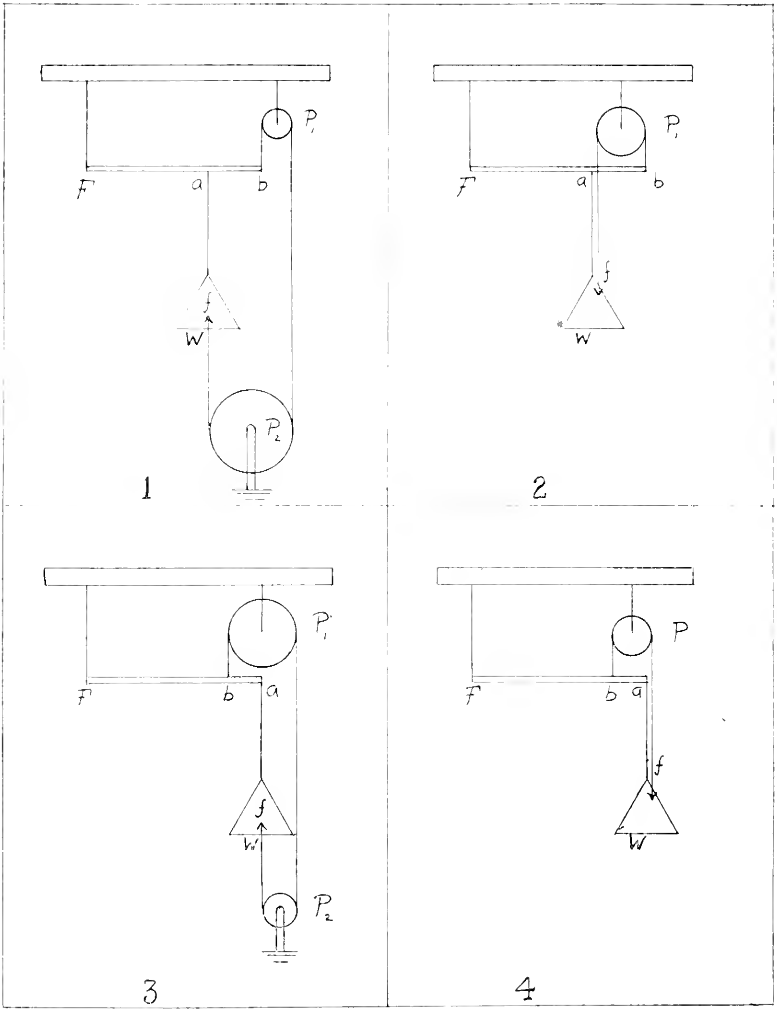

FIG. 17.

of W/m^3. Without going further we see that the total force he must exert is represented by the infinite series

$$f = W/m + W/m^2 + W/m^3 + W/m^4 + \ldots\ldots\ldots \qquad (3)$$

By equating equations (2) and (3), and cancelling the W's, we obtain the following series:

$$1/m+1/m^2+1/m^3+1/m^4+\ldots\ldots\ldots=1/(m-1) \quad (4)$$

This is the correct summation of the series and the series is convergent, since we assumed m to be greater than unity. Hence the two methods of approach are equally good, and both lead to the correct answer.

It is a matter of some interest to speculate as to which method would be used by a man on an actual platform of this kind. It seems that the algebraic method would certainly not be used. Either his muscles would gradually exert tension in the manner represented by equation (3), or else he would approach the correct force by an oscillatory muscular pull, the oscillations gradually getting smaller and smaller until the correct force f has been reached. This type of series will be found in the discussion below. Such a problem as this, aside from these psychological aspects, cannot help but be of some value to a teacher of elementary physics or mathematics in that it gives a tangible meaning to an infinite series. Of course there are many other problems that will illustrate this particular point.

Consider now the arrangement shown in diagram 2. The reaction is now opposite in direction to W, and the algebraic solution is given by

$$W-f=mf \quad (5)$$

or

$$f=W/(m+1) \quad (6)$$

The other method of obtaining f is somewhat similar to the preceding one. A first pull of W/m is necessary. This pull, however, decreases the load by W/m, and therefore the tension in the rope must be slacked by an amount W/m^2. This in turn adds to the thrust on the platform of W/m^2, and an additional pull of W/m^3 must be exerted. In short the force is determined by the following series:

$$f=W/m-W/m^2+W/m^3-W/m^4+\ldots\ldots \quad (7)$$

Equating equations (6), and (7), and cancelling the W's we obtain

$$1/m-1/m^2+1/m^3-1/m^4+\ldots=1/(m+1) \quad (8)$$

As long as m is greater than unity this is a convergent series and is correctly summed. Here again then we have the two methods of attack leading in one case to a simple answer, and in the other to an infinite converging series, the series being a correct representation of the algebraic result.

Turning now to the arrangement shown in diagram *3* we arrive, by the two methods of approach to equations identical with equations (2) and (3), respectively. However, in this case, m is less than unity, so that equation (2) leads to a negative value for f, which means that no positive pull will yield equilibrium, and hence that the physical solution is impossible. The discussion of the two cases when m equals unity is obvious. The series (3) becomes now a divergent series, and cannot be summed. Here then the second method of approach fails to yield any result, whereas the algebraic method does yield a result although it has no physical reality. A glance at the divergent series (3) shows that the man is forced to exert a greater and greater pull, which situation would no doubt correspond with the facts in an actual situation. But the more the man pulls the more certain he is of falling to the ground.

The most interesting case, however, is the last one, represented in diagram *4*. Here we arrive by the two methods of approach at equations (6) and (7), respectively. The algebraic solution (6), is perfectly definite and physically possible, even when m is less than unity. However, the series (7) is divergent, when m is less than unity, and ordinarily considered it has no sum. A glance at the series will show that the man first pulls with a certain force, then relaxes the tension by a greater amount, next pulls with a still greater force, and so on, pulling and relaxing with forces ever increasing in magnitude. It is evident that this latter method would not be the actual one, and it again becomes a matter of interesting speculation as to with what rhythmical, or other, muscular efforts the man arrives at the correct force for equilibrium. It is possible that the terms of the divergent series (7) could be grouped in a certain fashion to yield a convergent series which would have the correct sum.

It is evident that the second method of analysis of the problem succeeds in cases shown in diagrams 1 and 2, for all values of m greater than unity, fails in *3*, for m is less than unity, but fails because the solution is impossible, and fails utterly in *4* for values of m less than unity, although the solution of the problem is possible and perfectly definite.

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THE TUNGSTEN X-RAY SPECTRUM.

ELMER DERSHEM.

Some work has recently been done in this laboratory in the analysis of the molecular arrangement in certain crystals by means of the reflection of X-rays from these crystals. To carry out this work it was first necessary to determine the wave lengths of the characteristic lines of the tungsten X-ray spectrum because tungsten is the material of the anticathode of the Coolidge X-ray tube, the most satisfactory tube for this kind of work.

The method of obtaining the X-ray spectra was essentially the same as that used by many other X-ray investigators. A crystal was mounted inside a lead box in such a way that it would be slowly and uniformly rotated by means of the rising of a float in a tank into which water from a constant head source was allowed to flow. A cleavage face of the crystal was placed in the vertical axis of rotation and X-rays coming through a narrow vertical slit in the lead shield between the crystal and the tube were reflected from the crystal whenever the angle made by the crystal planes with the incident rays satisfied the condition given by the formula $n\lambda = 2d \sin \theta$ in which n is a whole number, the order of the spectrum, λ is the wave length, d is the distance between planes parallel to the face in question and θ the angle between these planes and the incident rays. A photographic plate was placed inside the lead box and with its plane perpendicular to the line joining the crystal and the source of X-rays. In this position it would receive and register a vertical line, or image of the slit, whenever the angle of the crystal was such as to accommodate, according to the above formula, any wave length existing in the X-ray spectrum of tungsten. The distance along the plate from the center to the position of any one of the lines and the distance from the axis of rotation of the crystal to the plate being known it is easy to determine the angle of reflection since the ratio of these distances gives the tangent of twice this angle.

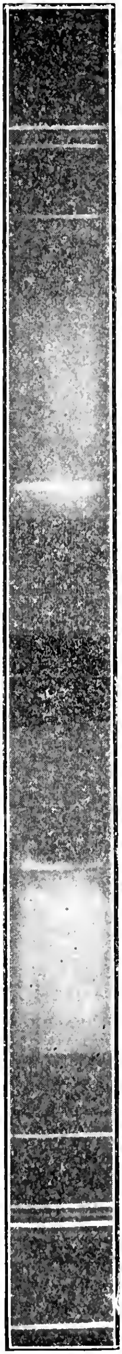

FIG. 18.

In experimenting with crystals which absorbed X-rays only slightly, it was found that the lines on the photographic plate became wide and overlapped, making it impossible to perceive any spectral lines whatever, the plate giving the apearance of a continuous spectrum. A study of the conditions which would cause this led to the conclusion that the resolving power of a crystal, or its ability to separate lines of nearly the same wave length could be increased by making the crystal very thin. A test was made, using a crystal of rock salt which had been ground to a thickness of 0.2 mm. The results amply justified the theory as the lines were narrower and sharper and lines appeared in a region which had previously been considered as a region of continuous spectra only. A print from this plate is shown in figure 18.

It is impossible to reproduce the finest lines which appear on the plate. In taking this photograph the crystal was first rotated through the position which would give the tungsten spectrum on one side of the center line and then reversed to give the spectrum on the other side. In this way the distance between the two positions of a line is twice the displacement distance of that line. In this case the crystal was rotated about an axis passing through one of its faces and which was 15.553 centimeters from the plate. The distance between the two positions of the strong line of greatest wave length was 18.248 centimeters. One-half of this, 9.124, when divided by 15.553, gives the tangent of twice the angle of reflection which is found to be 30° 24′. The angle of reflection is therefore 15° 12′.

In the following table the values of the X-ray wave lengths of tungsten are given. The computations are based on the value of 2.814×10^{-8} cm. as given by Bragg for the distance between planes in a rock salt crystal.

	Glancing Angle of Reflection	Wave Length
	15° 17′	1.483x10⁻⁸ cm.
Strong	15° 12′	1.476
	13° 21.5′	1.300
Strong	13° 11′	1.284
	12° 57.5′	1.262
Strong	12° 46.5′	1.244
	11° 35′	1.130
Strong	11° 16′	1.100
	10° 52′	1.061
	10° 31′	1.027
	9° 52′	.964
	9° 22.5′	.917
	7° 33′	.739
	4° 55.5′	.483

Other measurements indicate that these values, assuming the exactness of the above value of d, are correct to within 0.1 per cent. It is the belief of the writer that the resolving power of a crystal may be much further increased and the X-ray spectrum of the elements made almost, if not quite, as extended as the light spectrum and by means of this greater resolving power the finer details of atomic structure become known.

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State University of Iowa.

A CURVE OF MOISTURE CONDENSATION ON GLASS WOOL.

L. E. DODD.

Experimental results of Professor F. T. Trouton[1] relating to equilibrium vapor pressure and total mass of water vapor fed to glass wool that had previously been thoroughly dried, showed an interesting drop in the curve at about half saturation pressure. The character of the curve appeared to afford grounds for a theory, proposed by Trouton, which supposed the condensation to have taken place in two modes, or states, which he called the alpha and the beta states. After thorough drying, employing the three agencies of continued vacuum, phosphorus pentoxide, and a temperature of about 160°, moisture in the alpha state was supposed to condense on the dried surface first. The alpha condensation required relatively only a small amount of water. With the equilibrium pressure at about half the saturation value, which followed after but two or three feeds, and with additional water fed to the glass wool, the equilibrium pressure dropped, at which time the beta condensation was supposed to have begun, following a condition of supersaturation. The alpha condensation was interpreted as forming a nucleus for the beta type. After a few more feeds the curve rose again toward saturation. Trouton took the view that his results were theoretically to be expected from the shape of curve given by a characteristic gas equation, and that the same results could be expected from surfaces in general that had been in like manner thoroughly dried. More recent work by Mohr[2] and by Gossrau[3] has, however, thrown doubt on the supposition that Trouton's results are simply a response to the demands of the characteristic gas equation. These investigators found that the Trouton effect, i. e., the drop in the pressure-mass curve, was present only in the case of alkali glasses.

With Trouton's theory in view, before the work of Mohr and of Gossrau had become known, and in view also of experimental

[1]Trouton, F. T., Proc. Roy. Soc., Ser. A, 79, July 10, 1907, p. 383.
[2]Mohr, Erich: "Ueber Adsorption und Kondensation von Wasserdampf an blanken Glasflächen," Inaug. Dissert., Halle, 1911.
[3]Gossrau, Gotthard: "Untersuchungen über Adsorption von Wasserdampf an blanken Glasflächen," Inaug. Dissert., Halle, 1913.

results obtained in this laboratory by Stewart and by Brown as well as by the writer, which indicated the presence of electrical conduction between metal electrodes in air without actual metallic contact of the surfaces, it was proposed by Stewart to use Trouton's experimental method on metallic surfaces instead of glass. The possibility was entertained that the pressure-mass curve in the case of a metal would show the Trouton effect so definitely that the beta condensation, or a similar type of condensation, could be held responsible for electrical conduction across the gap observed to occur at a much larger distance between electrodes on a very humid day. It was hoped that the Trouton drop in the case of a metal would be found near saturation.

The first metal tried was copper. It was considered desirable to experiment simultaneously with glass wool in a separate apparatus of the same kind, in order to learn whether the present experimental conditions, somewhat modified from those of Trouton, would give the same character of curve he obtained. The outstanding modification of Trouton's apparatus was a very great refinement in the mode of feeding water into the glass wool

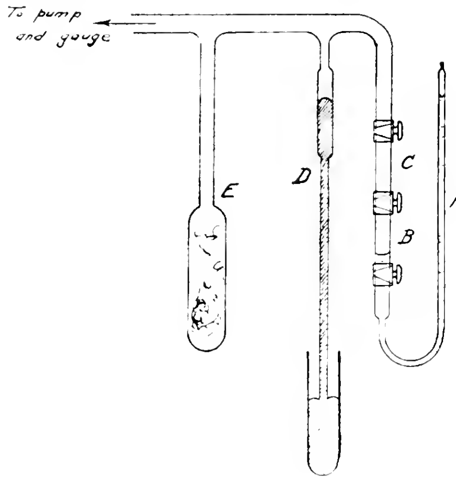

FIG. 19.

chamber subsequently to the drying, a refinement suggested by F. C. Brown. Without describing in the present report the results with copper, only the results with glass wool will be considered.

Figure 19 shows the apparatus. The tube A contains distilled water freed from air. B is a chamber between stopcocks to contain a small amount of water from A. C is another chamber between stopcocks, the "feed chamber." A mercury manometer, D, is for the purpose of reading pressures inside the apparatus. E is the bulb containing the glass wool. The tube marked "to pump and gauge" was sealed off following the drying process and before any water feeds were let into the apparatus.

The method of feeding was to saturate the feed chamber with water vapor, and then open this chamber into the apparatus, the stopcock between it and chamber B having first been closed. In Trouton's apparatus the feed was made from a capillary chamber (with a similar arrangement of stopcocks) filled with water in the liquid state. Thus the amount of water let in at any one feed was much greater than in the modified method, and Trouton could get only two or three separate feeds into his apparatus before the phenomenon of pressure drop occurred. Likewise in the part of the curve immediately following this drop only a general notion of what was actually taking place could be obtained because of the few readings in this region.

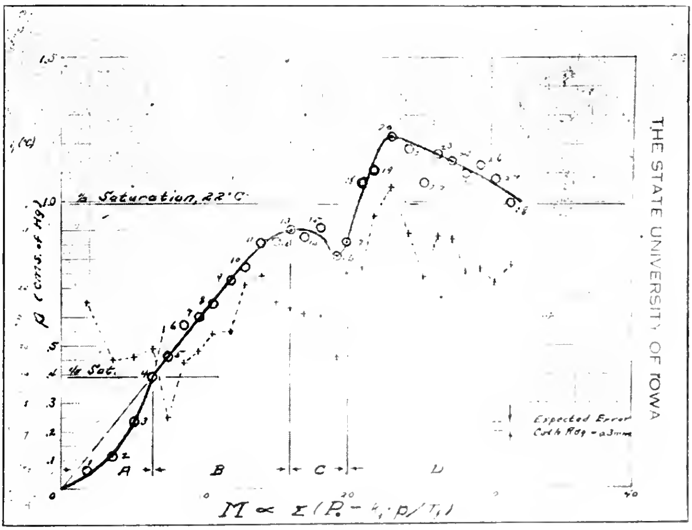

FIG. 20.

Trouton's method of drying was to immerse the wool chamber in hot oil kept at the desired temperature as long as the drying continued. In the present work an electric oven served, without the use of oil. The drying continued for three days and nights at a temperature of at least 200°, with a Gaede mercury pump continually running, and in the presence of phosphorus pentoxide.

The data for the curve, figure 20, connecting equilibrium pressure and total mass of water, were taken over a period of seven or eight months, and while the curve is not yet complete to saturation the experiment has been carried far enough to reveal several matters of interest, mentioned in the summary. In this curve the separate feeds are numbered. Following any one feed more readings than one were of course taken, sometimes a series of readings extending over considerable time.

SUMMARY OF RESULTS.

1. The curve is of particular interest because of the larger number of separate feeds before the half saturation region is reached, showing a refinement much greater than in the Trouton method.

2. The curve is divided into three distinct parts: A, B, C-D.

3. An examination of the ratio y/x^2 for part A of the curve shows that this part approaches very close to the parabolic form.

4. Part B of the curve may be taken as linear, and when projected it passes through the origin.

5. Part C-D is a region of more or less instability.

6. In part A of the curve more time was required, in general, for the pressue to reach the equilibrium value than in the other region, where the equilibrium pressure ensued in a relatively short time after a feed.

7. Although the pressure data used in the curve were corrected to a constant temperature of 22° C. there still appears a marked fluctuation of pressure with the actual temperature prevailing at the time the reading was taken, and generally in the direction one would expect. This effect not only appears in the main curve shown, but also in auxiliary curves using series of readings taken between actual feeds. The effect is to be explained by the change with temperature of the mass of water present as vapor, while the pressure correction for temperature assumed a constant mass of water vapor. There would appear to be sufficient data for information as to how the mass of water in the condensed film varies with temperature.

8. There is no noticeable change in pressure with time, which shows the absence of air leak into the apparatus, in spite of the presence of two stopcocks that might be expected to afford some leak. This result may be laid to a careful regrinding with fine emery and water before use.

THE STROBOSCOPIC EFFECT BY DIRECT REFLECTION OF LIGHT FROM VIBRATING MIRRORS.

L. E. DODD.

A very simple and convenient method of producing the stroboscopic effect is to reflect light directly from a vibrating mirror upon a stroboscopic screen. The mirror may be such as is afforded by a vibrating membrane which is itself reflecting or has a suitable mirror attached either directly or indirectly to it.

Any stroboscopic apparatus is divided into two principal parts, the stroboscopic screen arrangement with its similar figures in motion, and some means of obtaining periodic glimpses of the screen. The latter is commonly provided by some method of periodic illumination with suitable frequency. The manometric gas flame is the device most commonly used to produce periodic illumination, although a periodic electric spark, or a discharge tube with tuning fork interruptor of the induction coil primary, give good results. The important condition of illumination for producing the stroboscopic effect is that there shall be in any given small region of the screen the periodic change in light intensity. (It is not necessary that the light be at any time entirely reduced to zero intensity.) Given such a small region on the screen and the similar figures of suitable size, the stroboscopic effect will occur in this region if the latter undergoes a periodic change in the intensity of the light falling upon it, regardless of how this change is produced.

There are in general two possible ways in which the light intensity in the region of small area can change: (1) by a change in the intensity of the beam of light as a whole, which falls on the screen, with the beam itself possessing at any instant a uniform intensity over its cross-section, or (2) by a periodic back and forth lateral displacement of a beam whose intensity does not vary with time, but is non-uniform over the cross-section of the beam. The writer has no knowledge that this latter way has heretofore been employed to produce the stroboscopic effect.

In the case of a vibrating membrane which is itself reflecting we have of course a mirror that changes periodically from convex to plane to concave and back again, and hence a beam of light reflected from its surface to a screen will periodically change its total area of cross-section where it is intercepted at the screen. Since the total quantity of light in the beam does not change, the intensity of light in the spot on the screen varies inversely as the area included in the spot. This would give then on the screen a periodic illumination of the first general type mentioned.

Alexander Graham Bell[1] used such a reflecting membrane in his photophone, permitting the beam of light to fall upon a selenium cell. A telephone receiver in series with the cell reproduced the tone actuating the membrane. Bell explained the effect on the light sensitive cell by the changing curvature of the mirror, as described.

The explanation appears to be the obvious one, simple and final. It would appear to be justified also in the light of other experimental results obtained by Professor Bell. He constructed a hollow convex lens with walls of mica or thin glass, and filled it with a transparent liquid or gas. The walls of the lens could be made to vibrate under the action of the voice, and thus the lens curvature could be periodically changed. A beam of light passing through the lens and falling upon the selenium cell produced the same effects in the telephone receiver as the vibrating mirror.

But, taking the case of the mirror, it must be remembered that the amplitude of vibration is not large, and hence the curvature changes over only a very narrow range. One would hardly expect therefore that there could be a change in the intensity of the beam of any consequence, at least for very short distances between mirror and screen at which the stroboscopic effect can be produced. With larger distances, as in Professor Bell's work with the photophone, the effect is of course considerably greater.

[1]Bell, A. G.: "De la production et de la reproduction du son par la lumière," Annal. de Chimie et de Physique, t. XXI, 1880.

Professor Bell's explanation, in view of his results with both the vibrating mirror and the vibrating lens, of the light effect on the selenium cell may be taken as at least partial explanation of the phenomenon. However, in both cases of mirror and lens, as the cross section of the beam alternately contracts and expands, there must be a lateral displacement increasing in amount toward the margin of the beam. If the beam is not of perfectly uniform intensity over its cross section, and it is not likely to be, at any particular fixed point where the beam falls there will be changing intensity due not only to its expansion and contraction, but also to the fact that a little element of the beam incident at this fixed point is being replaced by an adjacent element of different intensity, different because of the non-uniformity of the beam. Because of the relatively small amplitude of the membrane the lateral displacement of the beam cannot be very large, especially at short distances, and yet it is sufficiently large to give the stroboscopic effect even in the case of spots of 3 or 4 mm. diameter on the stroboscopic screen, and that at relatively short distances. It cannot be supposed therefore that the lateral displacement is sufficient to cause an element of the beam to sweep clear across one of these larger spots.

It would seem that we cannot be at all certain without further investigation as to just how important a role this effect due to a non-uniform beam plays in the experimental results of Bell with a selenium cell. We may, however, be certain that it is present in both the case of the vibrating mirror and that of the vibrating lens.

One is justified in suspecting that it does play some part in Bell's results, in view of the results in stroboscopy obtained by the author. For the stroboscopic effect has been found to exist very sharply when the vibrating mirror was made by silvering one of the small circular microscope cover glasses and attaching it to a vibrating membrane by means of a bit of cork between them. Under these circumstances it is not to be expected that the mirror will change its curvature when the membrane vibrates, but will move as a whole. Moreover the stroboscopic effect was produced with a piece of ordinary mirror glass, attached to the membrane. This mirror glass was much too thick to admit the possibility of changing curvature. It appears therefore that the stroboscopic effect is to be explained, in large part at least, by the periodic lateral displacement of a beam of non-uniform intensity over its cross section. We are thus led to suspect that this same condition, present in Bell's work, played its part in the effect on the selenium cell. It is more difficult, however, to accept such a conclusion in the case of the cell's response, than in that of the production of the stroboscopic effect. In the former the total amount of light falling upon the cell must remain very nearly the same, even though at any particular point on the cell the intensity changes by the lateral displacement, while in the latter case it is a region of small area that is chiefly concerned.

In a consideration of the stroboscopic effect the fact must not be overlooked that the eye is extremely sensitive to small changes of light intensity, so that the changing area of the beam on the screen may contribute its effect, which, however, appears to be at most only a minor effect. The decisive experiment must have achieved a separation of the two mechanical conditions, that of periodic expansion and contraction of the beam with the accompanying changes in light intensity due to this expansion and contraction alone, and secondly, the periodic lateral displacement of the beam. It is easy to have the second condition alone present, as has been shown, but it is difficult to see how one could have changing curvature without lateral displacement.

While the idea of reflecting light directly from a vibrating membrane was arrived at independently by the author it was later learned that the idea was anticipated by Professor Bell about 1880, who, however, used the reflected light for a different purpose. The production of the stroboscopic effect by this method appears to be new.

In this method various kinds of diaphragms can be used. Satisfactory results have been attained with silvered mica membranes, as well as paper and rubber dam membranes (with mica mirrors attached to them either directly with paste or with bits of cork or cardboard between mirror and membrane.) Paper membranes seem to give as good results as any.

A of figure 21 shows an arrangement of a paper membrane over the end of a short glass tube, with a lever system and a small mirror (microscope cover glass) that could periodically be given an angular displacement by the vibrating membrane actuated by a sounded tone at the open end of the tube. This was one of the preliminary experiments to find a method to replace that of the manometric flame, for the purpose of stroboscopy. A reflected beam falling on a rotating mirror gave

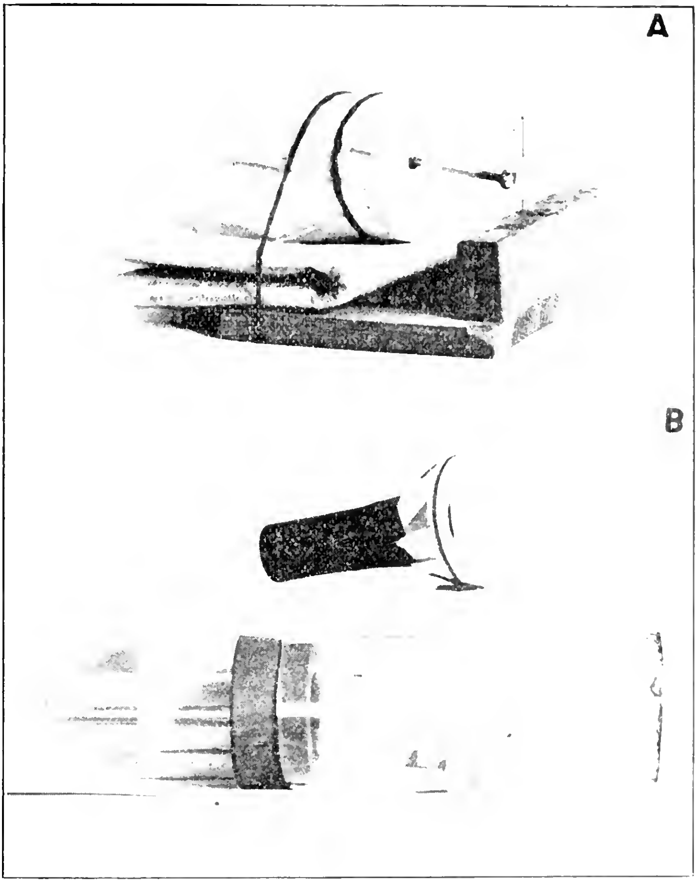

FIG. 21.

clearly defined sine waves of large amplitude. A simple step from this arrangement was to attach the small mirror directly to the membrane, and then to use a mica membrane that could be entirely silvered.

B of figure 21 shows, above, a reflecting membrane made by stretching paper over the large end of a telephone receiver shell with the cap off, and to the paper attaching as already indicated a mica mirror. Below is shown a glass tube arrangement as vibrating chamber, with the right end of the large tube covered with a silvered mica membrane. The left end of the smaller tube served for mouthpiece. Leaning against the large tube in the foreground is seen a circular piece of silvered mica such as was used for a reflecting membrane.

SUMMARY.

1. A new and simple method has been found for producing the stroboscopic effect.

2. The method appears to employ a general means of producing periodic illumination changes at a fixed point which has not been hitherto used; viz., the periodic lateral displacement of a beam of light non-uniform in intensity over its cross section.

3. A question for further investigation is: How large a contribution to the changing light intensity on the stroboscopic screen is due to changing curvature of the mirror?

4. An additional experiment suggested by the stroboscopic effect with the vibrating mirror is a similar experiment with a vibrating convex lens, similar to that used by Bell with a selenium cell.

A NEW TONOSCOPE.

L. E. DODD.

While undergoing a series of voice pitch tests some three years ago in the Psychological Laboratory of the State University of Iowa, the author learned that in his own individual case, as in some others, there existed, according to the statement of the investigator, Mr. C. J. Knock, a consistent as well as persistent tendency to miss in a definite direction certain intervals of the musical scale. The instrument used in these tests was the Seashore tonoscope,[1] an indicator of absolute pitch developed in some of its later stages at this University. In the particular results mentioned the amount of the error was not so noticeable to the ear, as the ear has its limitations, especially when it is the ear of the one who is himself forming the intervals by voice, but in an absolute instrument like the tonoscope even very small errors can be detected. The conclusion formed by the author from these results was that the musical intervals concerned had been wrongly learned in childhood.

[1]Seashore, C. E.: Psych. Monographs, University of Iowa Studies in Psychology, No. VI, June 1914, p. 1.

The sources of a child's information regarding musical intervals are his listening to a piano or other musical instrument, or his hearing the intervals sounded by almost anyone who may be at hand to do this for his benefit. The chief difficulty with the first method is that the instrument may be and generally is, to an extent at least, out of tune, and in the second case the fidelity to pitch of the older person who is sounding the intervals is more or less questionable, depending both upon how good a musician this person is and also upon his physical condition, which has a marked effect upon one's fidelity to pitch.

A child's first impression is the important impression. In the interest of making his first impressions regarding matters of pitch in singing as nearly absolutely correct as possible an instrument like the tonoscope should be made readily available to the public. In fact it should be an instrument available in the home itself. Availability includes as small size and weight as possible together with low cost.

The idea of improving the tonoscope in at least these respects has continued with the author since the series of tests to which reference has been made. In February of the present year (1916) experimental work was undertaken with a view to simplifying the instrument. This resulted in a new method of producing the stroboscopic effect which is particularly adapted to the tonoscope because it does away with the manometric flame and its necessary gas supply. It also permits the illumination to come from one end of the drum rather than directly in front of it. The new method is presented in a separate paper.

It was also found by stroboscopic tests that a mechanical clockwork meter of the phonograph type possesses a marked constancy of motion, which over an interval of about two minutes is constant to within one-tenth vibration per second. By introducing an electric wind to keep the spring automatically at the same tension very great constancy can be secured and thus the special synchronous motor for constant speed rendered unnecessary. Also it was found that the stroboscopic drum could be greatly reduced in size, and both drum and scale placed at the distance of most distinct vision from the eyes.

Thus there has resulted an improved tonoscope that has the desirable qualities of portability and reduced cost of manufacture. It is an instrument easily available to the home and the public school, as well as to music teachers and musicians everywhere, in private studios or conservatories. Because of its wide

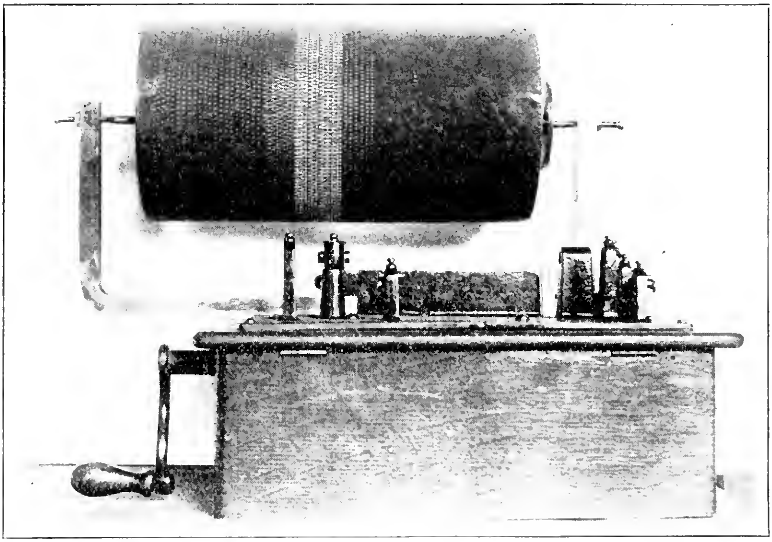

FIG. 22.

availability science will have at hand practically unlimited amounts of data to be used in drawing scientific conclusions, or formulating laws.

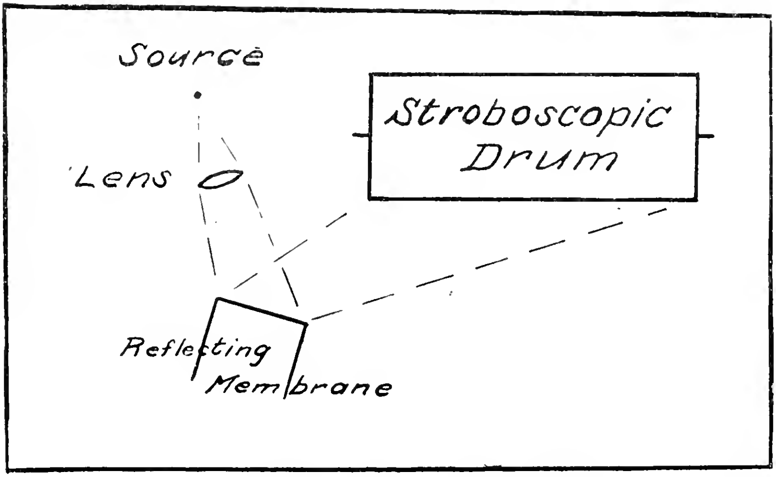

FIG. 23—Lighting Scheme in New Tonoscope.

Its uses are numerous, but none would seem to be more important than its employment in giving to children correct impressions as their first impressions regarding matters of pitch. For a child to be at all musical he must learn the musical scale. The scale is fundamental although simple and usually quickly learned by the child, and a little time spent with him with the tonoscope as an aid will give him these correct impressions.

The stroboscopic drum with its phonograph motor drive used in the demonstration of the new tonoscope at Des Moines is shown in figure 22. The lighting scheme for the stroboscopic method is indicated in figure 23.

PHYSICS LABORATORY,
STATE UNIVERSITY.

AN ELECTRICAL DEVICE FOR SECURING AND MAINTAINING CONSTANT HIGH TEMPERATURES.

W. E. TISDALE.

In a paper read before this Academy last year, a device for controlling comparatively high temperatures (up to about 600° C) was explained, together with the necessary auxiliary apparatus, an ordinary electro-magnet circuit breaker, and the source of constant potential necessary to operate this magnet. The oven described in that paper consisted of a properly insulated porcelain tube 30 cm. long and 5 cm. in diameter. It required 10 amperes to heat it to 450° C. The dimensions of the oven limited the size of the tubes in which the crystals were to be produced to not more than 3 cm. in diameter and 15 cm. in length, and admitted but one at a time. Inasmuch as it requires several months to produce crystals of a size such as is necessary for optical and electrical work, the disadvantage of the oven may be readily seen.

In the catalogues of the various manufacturers of regulated electrical ovens, there are no descriptions of ovens that go above 300° C, so that the only method of obtaining one that would suit our purposes was to manufacture it ourselves.

Accordingly, the oven shown in figures 24 and 25 was designed. Except for the angle irons used in the corners, and the necessary bolts, it is made entirely of asbestos board three-eighths inch thick. The oven is double walled, the interspace on the sides being filled with loose asbestos, and that on the top with air. The inside dimensions are 12x12x14 inches, the longer dimension being the height. In figure 24 an elevation view is shown. The asbestos board with the double row of holes shown at the left in the figure is the bottom of the oven space, and belongs immediately above the heating coils, which may be seen in place on the bottom. The top shown tipped up is the top of the oven space, and between it and the top of the entire apparatus (shown in the front of the oven) is a space of three inches of air. The thermometer is seen projecting at the left, and on the inside the controlling device (figure 26) is seen in position hanging on the right wall. In figure 25 a plan view is shown, with the tops and the bottom of the oven space removed. At the left is shown the electro-magnet device for breaking the current through the heating coils. This magnet is operated by a

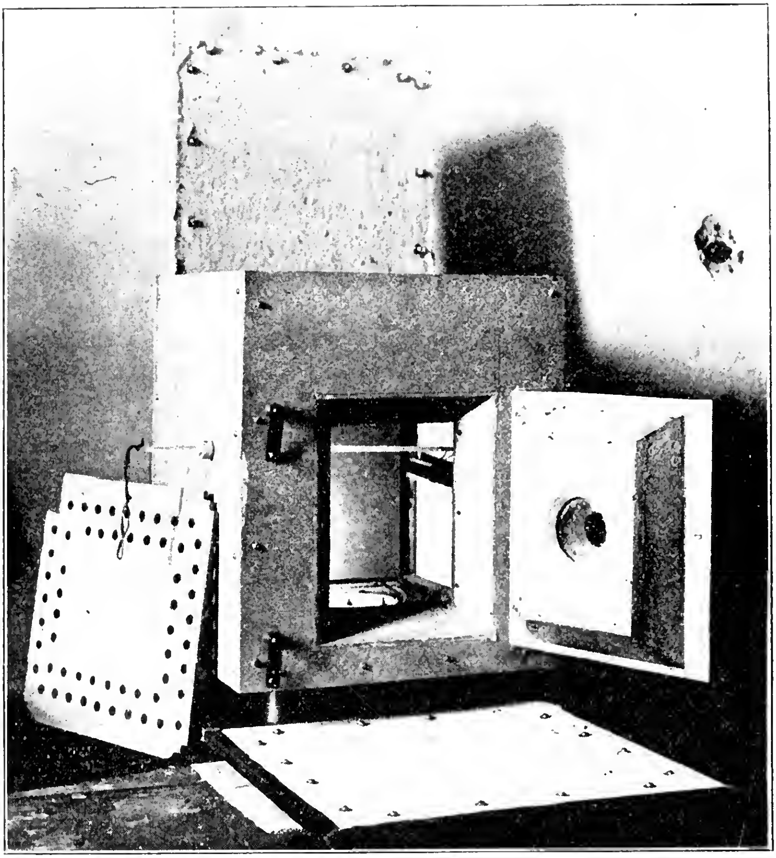

Fig. 24.

current controlled by the device shown in figure 26. This consists of a bar of asbestos board, to which is attached a thin metal strip. The gap shown between the silver tipped screw and the silver plug in the metal strip immediately below is 8 mm. This is the amount of rise of the center of the strip for a change of temperature from 20° C to 360° C.

The oven requires 8 amperes of current to heat it to 450° C, making the cost about 10 cents an hour to operate it at standard electrical rates. The controlling device regulates at 450° C to not more than one degree variation above or below this value, and has so maintained the temperature for the six weeks that it has been in constant operation. It is possible to maintain constant temperature with this apparatus up to 700° C, or about

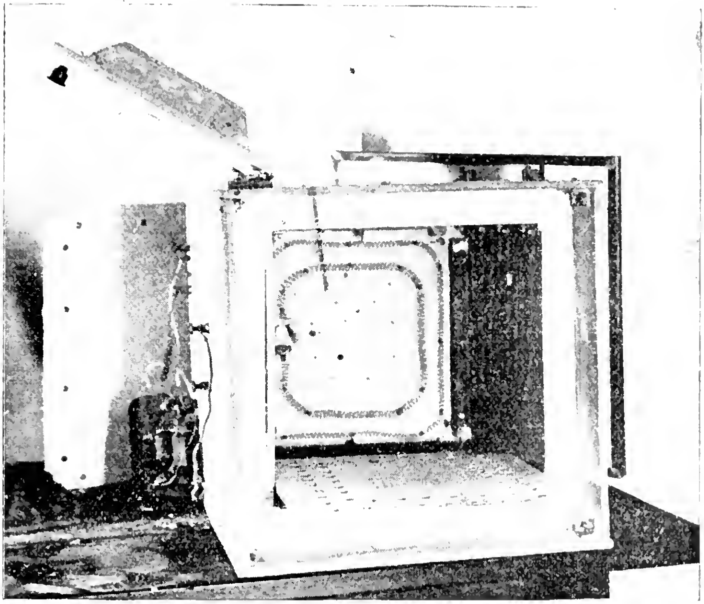

FIG. 25.

FIG. 26.

1300° F. The apparatus was made completely in the shop of the Physics department of the University of Iowa, at a cost for materials only of about $20.00. It has been entirely satisfactory in its results, having produced crystals for the researches of four different men.

PHYSICAL LABORATORY,
UNIVERSITY OF IOWA.

CERTAIN ELASTIC PROPERTIES OF PHOSPHOR-BRONZE WIRES.

A. J. OEHLER.

INTRODUCTION.

The work by Guthe[1], Guthe and Sieg[2], and Sieg[3], on platinum-iridium wires when used as suspensions for torsion pendulums, showed some remarkable elastic properties of that alloy. The principal one of these was the variation of the period with the amplitude of vibration. It was these studies that made it seem very desirable to test other alloys commonly used for suspensions, by a similar method.

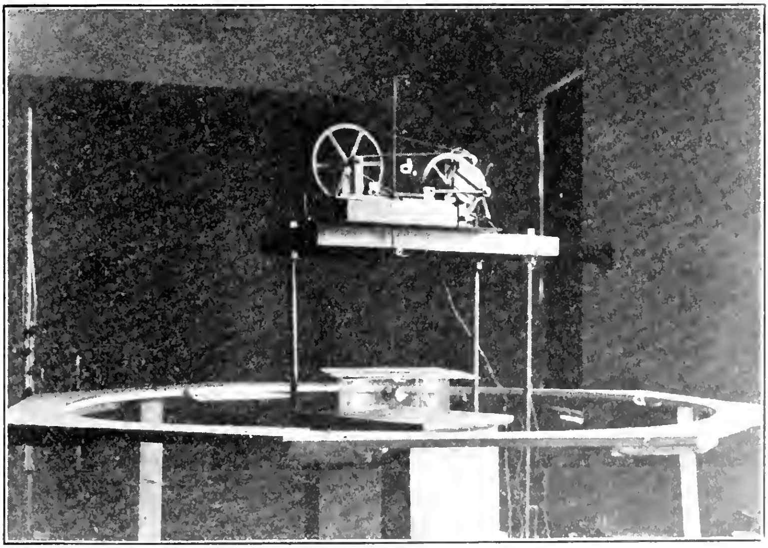

FIG. 27.

The wires employed in this research were of a phosphor-bronze alloy and represented thirteen successive drawings from an original sample. These ranged in diameter from .508 mm. to .100 mm. The wires were very kindly supplied by the American Electrical Works of Phillipsdale, Rhode Island.

[1]K. E. Guthe, Iowa Acad. Sci., 15, 1908, p. 147. Abst. in Phys. Rev., 26, p. 201, 1908.
[2]K. E. Guthe and L. P. Sieg, Phys. Rev., 30, 1910, p. 610.
[3]L. P. Sieg, Phys. Rev., 31, No. 4, 1910, p. 421.

THE PROBLEM.

The extensive use of phosphor-bronze wires as delicate suspensions, makes it very desirable to know intimately the elastic nature of this alloy. Some work by Professor Sieg and the writer in 1914, showed that the periods of the torsional vibrations were not constant but varied widely with different amplitudes.

The problem of this research was the verification of this elastic peculiarity and to prove that there is no justification for the use of these wires as delicate suspensions. New problems suggested themselves at once and some of these have been investigated to find out, if possible, more of the intimate nature of the alloy.

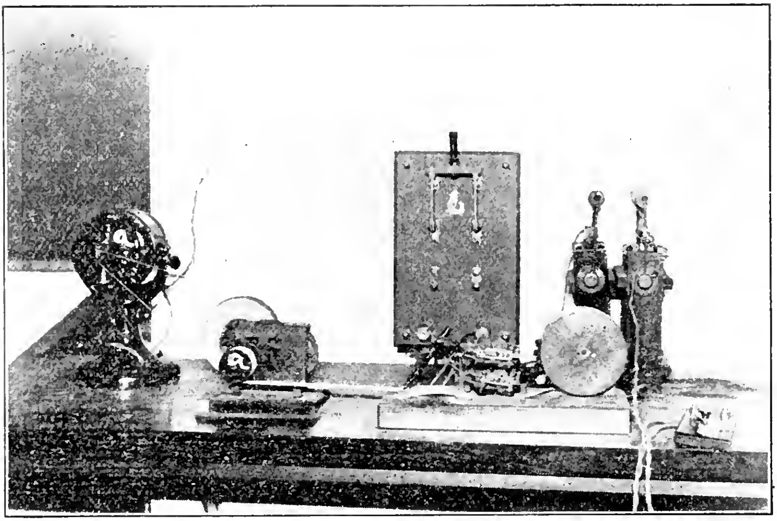

FIG. 28.

A preliminary report of certain of these experiments was given before the Iowa Academy of Science in the spring of 1915[4].

APPARATUS.

The apparatus is the same one which was employed and described by Sieg[5]. Figure 27 shows the complete apparatus with the exception of the arc which was used to illuminate the mirror, and figure 28 shows the timing device.

[4]Iowa Academy of Science, Vol. 22, 1915, p. 321.
[5]Loc. cit.

The length of the wire was usually 30 cms. and the initial twist in most cases was 10 degrees per cm. length of the suspension.

To make clear the method of observation, and the nature of the results, a sample of the data follows:

SAMPLE OF DATA.

(Wire No. 4, d=.145 mm; Load=154 g.; Approximate period=11.8 sec.)

Tape Readings	Corresponding Amplitudes	Average Time	Average Amplitude
3—32—19.85			
32—31.81			
32—43.63	254	3—32—43.62	
32—55.50			
33—07.29			
			215
3—36—39.85			
36—51.74			
37—03.47	176	3—37—03.46	
37—15.35			
37—27.00			
			149
3—41—46.30			
41—58.14			
42—09.84	122	3—42—09.87	
42—21.68			
42—33.41			

The above data were then tabulated in the following form:

Vib. No.	No. of vibs.	Ave. time (from above)	Time betw. Readings	Period (secs.)	Amp.	Ave. Amp.
		3—32—43.62			254	
11	22	3—37—03.46	259.86	11.812	176	215
35	26	3—42—09.87	306.39	11.784	122	149

The first column represents the number of vibrations that have been executed since the pendulum was set into vibration.

It might here be said that the elastic after effect was very marked in this alloy and so the zero point had to be re-determined several times during an experiment. The zero point was known to shift as far as nine degrees in the direction of the initial twist. This, of course, would introduce quite an error in the time readings if the above precautions were not taken.

THE RESULTS.

Introduction and general discussion. The experiments soon showed that there are three distinct states, from one to another of which the wires would change. The conditions under which these changes occur are very complicated but in this paper some of the conditions will be dealt with. The three period-ampli-

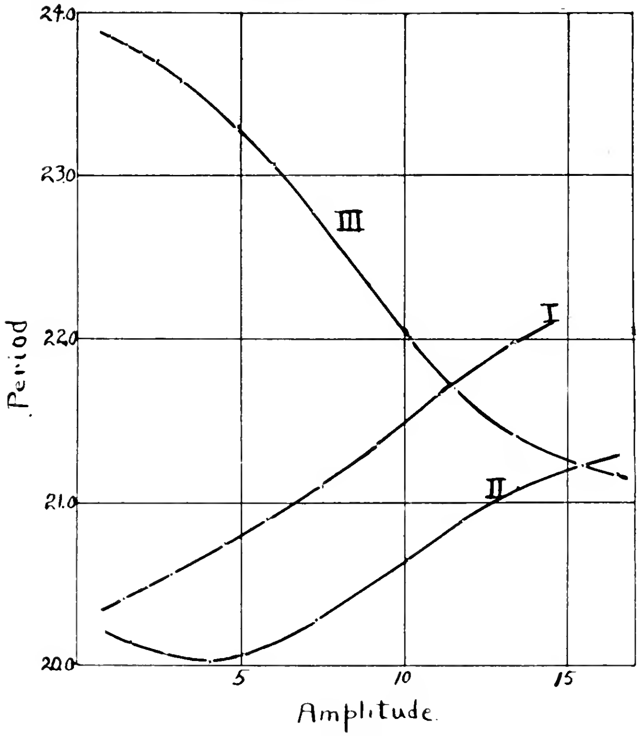

FIG. 29.

tude curves representing the three typical states are shown in figure 29. For convenience and brevity in discussion these will be numbered. They will be discussed in detail in the latter part of this paper.

Type I shall be the curve (see figure 29), in which there is a continual decrease in the period as the amplitude decreases. This departure from a constant period varies greatly in magnitude in the different wires and with the conditions imposed upon the experiment; as variations in the load and the approximate period. The same holds true also in the other types of curves. Wires when following this type of curve will be said to be in state I.

Type II is similar to the above mentioned curve in the larger amplitudes but makes a departure from that type at an amplitude of about four degrees per cm. length of the wire, and from that time on, the period gradually increases with a decrease in the amplitude. The curve is marked II (figure 29) and will represent state II.

Type III is seen to be very different from the other two. In this curve the period increases continually from the large to the small amplitudes. When the wires follow this type of curve they will be said to be in state III.

From figure 29 which shows three curves of an identical sample of wire under identical experimental conditions, it is at once seen that the variation from a constant period is very marked. The magnitude of the variation is perhaps best shown by going into these particular curves in detail.

The wire was .100 mm. in diameter (No. 1), and supported a load of 27 grams. Curve II is drawn from the data of June 6, 1915. All experiments of that time showed the wire to be in

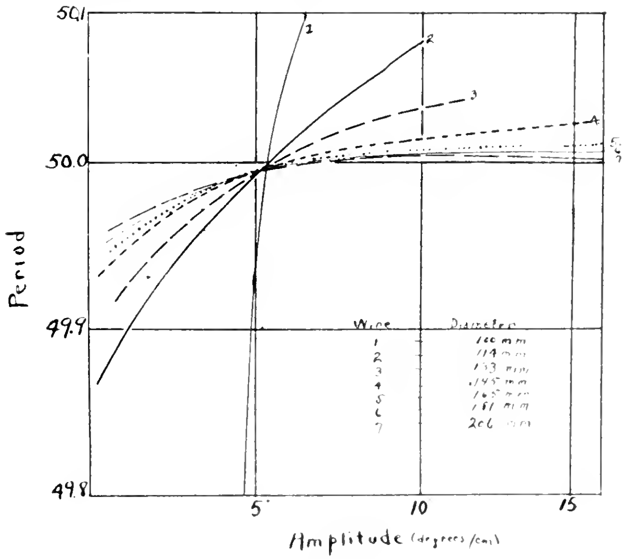

FIG. 30.

state II. The wire was then left hanging under its load through the summer months without vibration and in a room of practically constant temperature. On October 6, 1915, or four months later, the experiments were continued and the pendulum was set into vibration without any preliminary vibrations. The results of this test are shown in curve III. We see that the wire had changed from state II to state III in supporting its load during the summer.

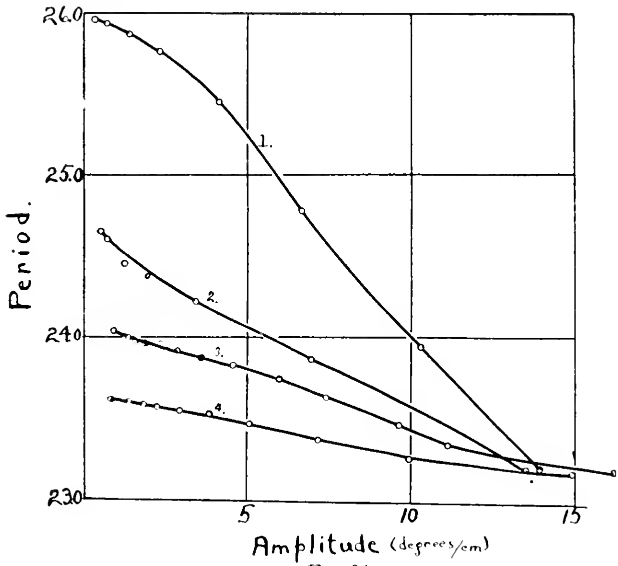

FIG 31.

From the coördinates it is readily seen that the maximum variation from a constant period, between the two curves, is about 3.85 seconds. Considering this variation with the maximum period of the two curves, it is found to be in the neighborhood of 16 per cent.

Curve I shows the identical sample of wire when in state I. It is seen that the variation from a constant period is not so marked in this type.

This phenomenon is found to be less marked as the diameter of the suspension becomes larger. In other words the drawing of the wires has a tendency to increase the effect. Figure 30 shows the results of experiments with seven successive drawings when the wires were in state I. Figure 31 shows the results of the four smallest of the above seven wires when in state III. The curves of each figure are reduced essentially, to a common period at a given amplitude. The diameter of the wires are given in figure 30. This result is similar to that found in platinum-iridium wires by Sieg[6].

[6]L. P. Sieg, Phys. Rev., Vol. 35, 1912, p. 347.

We may here note that the wires most commonly employed for suspensions are of a diameter in the neighborhood of the smallest of these wires.

Variation of Load and Period. The existence of these three states in the wires and their causes and relations then became the object of research. If the states existed, the wires of this alloy certainly were not reliable for use in scientific instruments. The question then arose as to whether the two variables, the period of vibration and the load supported by the wires, might not be the determining factors of the resulting state.

It was soon discovered that ordinary experimentation did not alter the condition of any sample of wire and so the experiments could be repeated many times while the wire remained in essentially the same state. It was found that unless the treatments were quite strenuous, the wires always behaved essentially the same. This was verified by repeating an experiment several times in succession and the curves were always

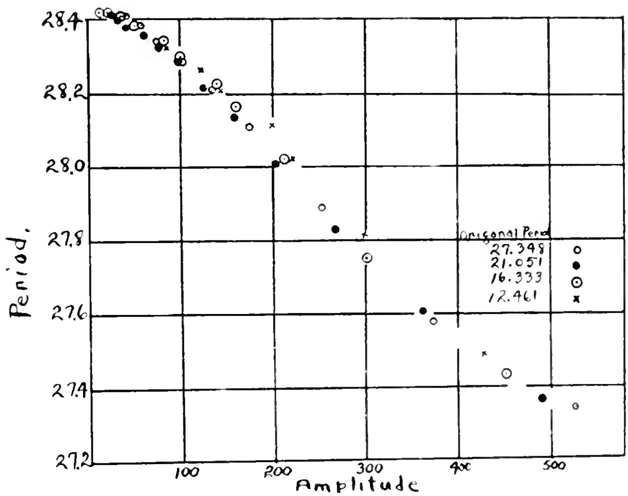

FIG. 32.

identical. In one case wire No. 3 (d=.133 mm.) was used over a period of nearly two months and the curves of this time are all of the same type.

To answer the above questions of a varying period and load, the following experiments were conducted:

Wire No. 3 was first used with four (4) widely varying periods of vibration but with a constant load and length of wire. The initial twist was the same in every case. The periods were varied by changing the moment of inertia of the pendulum.

Figure 32 shows the result of this experiment. It was immediately seen that the period-amplitude curves as well as the period-vibration number curves were similar in the four tests. Thus the period of vibration had no effect upon the state of the wire. Further than this, it was found that if each curve was multiplied by a certain factor the four curves fell practically upon a single line (see figure 32). The line has not been drawn, in order that the actual position of each curve may better be shown. The factors were simply the ratios of the periods at a certain amplitude, to any arbitrary number, and in this case they were 1, 1.3, 1.68 and 2.2. Table I below gives the original periods, the periods multiplied by the factor and the corresponding amplitudes.

TABLE I.

(1)		(2)		
K=1		K=1.3		
T.	Amp.	T.	K.xT.	Amp.
27.348	525	21.051	27.366	491
.574	373	.238	.609	360
.889	252	.414	.838	263
28.108	175	.544	28.007	205
.210	135	.644	.137	159
.292	102	.707	.219	125
.349	76	.755	.282	100
.375	58	.784	.319	79
.396	42.5	.812	.356	64
		.832	.382	52
		.823	.379	42
		.844	.297	35

[illegible]

K=1.06			K=[illegible]		
T.	KxT.	Amp.	T.	KxT.	Amp.
26.838	27.484	477	[illegible]	[illegible]	[illegible]
.522	.781	[illegible]	[illegible]	[illegible]	[illegible]
.577	28.014	[illegible]	[illegible]	28.0[illegible]	[illegible]
.754	.175	150	[illegible]	[illegible]	[illegible]
.806	.253	147	[illegible]	[illegible]	[illegible]
.848	.287	104	[illegible]	[illegible]	[illegible]
.878	.347	51.5	[illegible]	[illegible]	[illegible]
			[illegible]	[illegible]	[illegible]
			[illegible]	[illegible]	[illegible]
			[illegible]	[illegible]	[illegible]
			[illegible]	[illegible]	[illegible]

Having verified this relation [illegible] then investigated. In this [illegible] wire and initial amplitude [illegible]. At first an attempt was made to keep [illegible] different tests but because of the [illegible] pendulums, this was found to be a [illegible] and in view of the previous experiment was not [illegible] necessary. The results of this experiment are shown in figure [illegible].

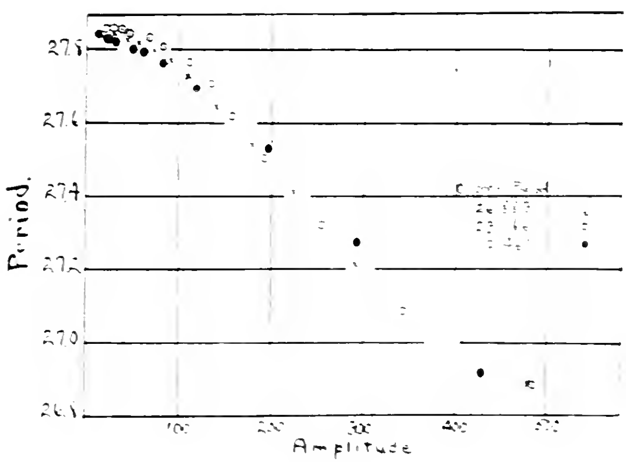

Fig. [illegible]

The same wire [illegible] was [illegible] and 272 grams. Again the [illegible] eral shape and [illegible] amplitude. Again the factors were simply the ratios of the periods to an arbitrary number. They were in this case 1, 1.16 and 2.16. Table II below gives the data of figure 33.

TABLE II.

(1) (2)

K=1		K=1.16		
T.	Amp.	T.	K.xT.	Amp.
26.833	483	23.166	26.873	490
27.094	342	.307	27.036	366
.325	255	.465	.219	288
.502	194	.624	.404	225
.618	158	.741	.540	179
.707	138	.826	.638	139
.760	112	.886	.708	109
.803	86	.930	.759	87
.835	66	.959	.792	70
.847	46	.978	.814	58
.859	29	.995	.834	47
.859	22	24.015	.857	38
		.007	.848	28

(3)

K=2.16		
T.	K.xT.	Amp.
12.461	26.915	428
.633	27.287	296
.744	.527	197
.813	.676	119
.849	.754	82.7
.863	.784	63
.870	.799	48
.885	.832	32
.888	.838	22
.891	.845	14.4
.890	.842	9.2

The variation from a single line here is somewhat more marked than in the previous table (I) where there was a constant load. The curve (figure 33) shows, however, that the varying load has no great effect upon the period-amplitude curve. The loads were so very wide in range that it seems safe to assume that ordinary variations in the load have no effect upon the action of the wire other than changing the period of vibration.

Variation of the length of the wire with constant load.—The lengths of the supporting wires were then varied from 30 cms. to 8.9 cms. and the period-amplitude curves were plotted both for variable and constant periods (approximate periods, since the periods were never constant), at the same amplitudes per unit length. When the pendulum had the same moment of inertia for each length the periods varied as the square root of the length of the wire. This was to be expected from the formula for the period of torsional vibrations,

$$T^2 = \frac{8 \pi I L}{n r^4}$$

where I is the moment of inertia of the pendulum, L the length of the suspension, n the coefficient of simple rigidity, and r the radius of the suspension wire. The periods must of course be taken at similar amplitudes. In this experiment everything was kept constant except the period and the length, therefore we would expect to find that

$$\frac{T}{\sqrt{L}} = K$$

The four lengths 30, 23, 15 and 8.9 cms. gave the values of K as 2.43, 2.47, 2.45 and 2.45 respectively.

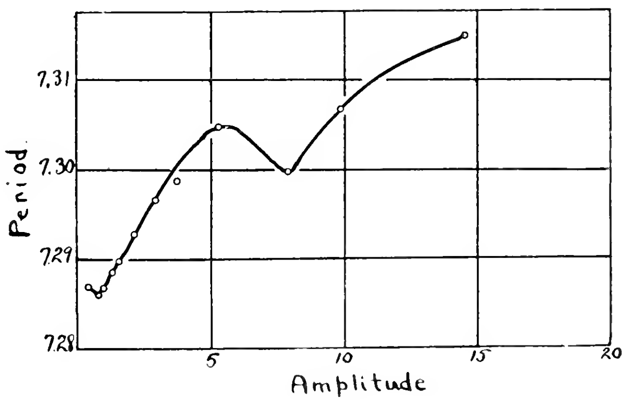

FIG. 34.

The period-amplitude curves for the shorter suspensions were somewhat unsatisfactory. The state remained the same in all cases as is shown by the general shape of the curves but the irregularities became very marked as the wire was shortened. These are not to be explained alone by the small error in the timing of the vibrations since the same tendency was noted also with the longer periods, where the error was the same as with

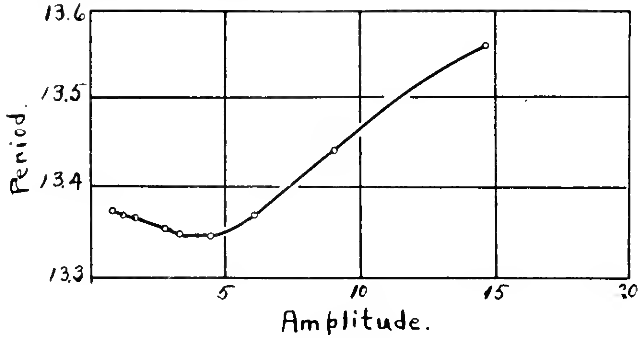

FIG. 35.

the longer suspensions. A comparison of figures 34, 35 and 36 will illustrate this point. All the curves are of wire No. 4 under a load of 154 grams. Figure 35 shows the period-amplitude curve for a 30 cm. suspension. The curve for a piece of

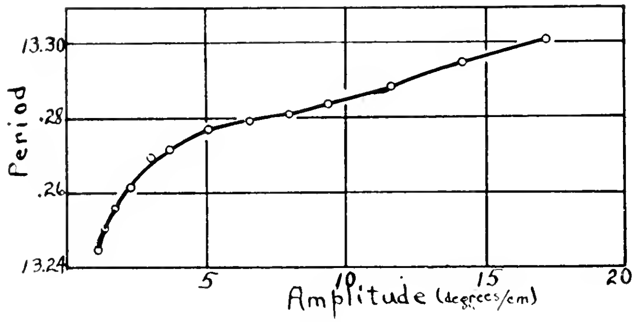

FIG. 36.

this wire, 8.9 cm. long, is shown in figure 34. Figure 36 shows the same piece vibrating with a period approximately the same as that of figure 35.

It is very probable that the shorter wires display more nearly the actual conditions in the wire whereas there may be a neutralization of some pecularities in the longer wires.

When the periods were kept constant with the above lengths the curves were somewhat more satisfactory but still had a great tendency toward irregularity. This point requires further investigation.

The most striking point to be discussed in connection with the data of these suspensions of different lengths, is that the number of vibrations required for the vibrating systems to fall between given amplitudes, increases as the wire is shortened. We can readily see that when the wire is shortest the displacement for a certain amplitude per unit length is smallest in magnitude. Since the periods were kept practically constant in these tests the angular velocity must have been greater in the longer suspensions.

Let us say that the average velocity varies as the angle of displacement and inversely as the period. Since the angle of displacement is arbitrarily taken proportional to the length, we have,

$$\bar{v}=kL/T$$

where v represents the mean velocity of the vibrating system, L the length of the wire, T the period and k a constant of the alloy.

Now assume the friction, both internal and external, to vary as the mean velocity of all the moving parts.[7] Then

$$c\bar{v} = KL/T = f$$

So, if we have variable lengths and periods we may say that if the friction is to be the same in all cases, the ratio of the lengths to the corresponding periods should be constant. (This would hold true no matter what assumptions are made in regard to the power of the velocity with which the friction varies.) Or we have

$$L/T=L'/T'$$

Now let N' be the number of vibrations between any two amplitudes per unit length and let N'' be the number for another length of the same wire between the same given amplitudes.

If N is inversely proportional to the friction,

$$N'=k/f'$$

and $$N''=k/f''$$

or $$N'/N''=f''/F'$$

but $$f=KL/T$$

thus $$N'L'/T'=N''L''/T''$$

but since the periods are kept constant $T'=T''$, and

$$N'L'=N''L''$$

or $$N'/N''=L''/L'$$

[7]The velocity of course is a continually varying quantity but the integrated value of the velocity over a whole period varies from v by only a constant, which is included in the constant k.

Thus we would expect that the number of vibrations executed between any two amplitudes should vary inversely as the length, if the above assumptions are correct.

Two specimens of wire No. 4 were employed in this experiment, one showing curves of type II and the other, curves of type III. The results of the wire in state II will be discussed first. The lengths used were 30, 23, 15 and 8.9 cms. Figure 57

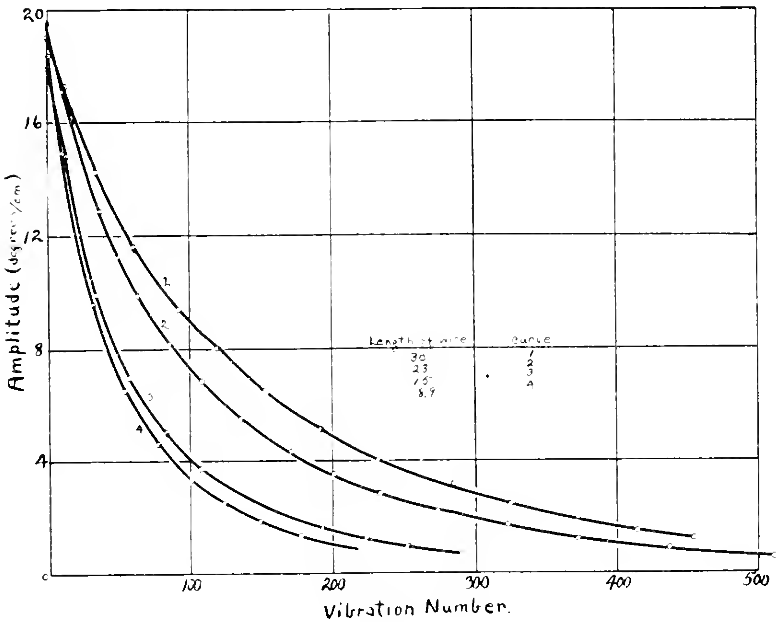

FIG. 37.

shows the vibration number-amplitude curves for the four lengths. The number of vibrations between any two common amplitudes per unit length can be interpolated from the curves.

It was found that there was essentially a constant ratio between the vibrations of any two curves, throughout the life of the vibrations. Table III gives some of the interpolated values from the four curves. The first column gives the lengths and each successive column gives the number of vibrations between the amplitudes given in the parentheses.

TABLE III.

LENGTH	N^1 (10-3)	N^2 (10-1.5)	N^3 (18-1.5)	N^4 (14-1.5)	N^5 (18-1)
30	80(1)	140(1)	170(1)	157(1)	206(1)
23	95(1.19)	169(1.21)	201(1.18)	186(1.18)	249(1.209)
15	166(2.08)	285(2.03)	340(2.00)	318(2.03)	416(2.02)
8.9	205(2.56)	330(2.36)	406(2.39)	377(2.40)	

The ratios are given for each N after the number. The number of vibrations of the longest wire is arbitrarily taken as unity in each case, and the ratios for the shorter wires are figured on this basis. The mean of the four ratios for each length are 1, 1.18, 2.03 and 2.43 with mean variations of 0, .01, .03 and .07 respectively.

The values for N.L are then 30, 27, 30.4 and 21.6.

In the case of the wire in state III the lengths were 30, 22, 15 and 10 cms. The values for the above ratios of numbers of vibrations in this case were 1, 1.72, 2.36 and 3.45. The values for N.L are thus 30, 37.8, 35.4 and 34.5. We see that the product N.L is roughly constant. It must be remembered that it was impossible to make the periods exactly equal in the different lengths, since the periods would have to be made equal at equal amplitudes per unit length of the suspensions. This was practically impossible. It is also evident that if the state of the wire changes we could hardly expect a constant friction. This point will be taken up again in the discussion of the loss of energy in the two states.

It should perhaps be said that the greater per cent of all the curves were either of type II or III and hence most of the data are on these curves. State I seems to be more or less unstable and is easily changed into state II. For these reasons type I is omitted from the discussion.

Variation of the initial amplitude. In a given sample of wire, the number of vibrations required for the system to fall through a given range of degrees, varies, in a general way, inversely with the mean amplitude of this range taken. In other words the fall in amplitude is exponential. This is common to all damped vibrations.

In the phosphor-bronze wires the initial amplitude determines how rapid this fall shall be. If the initial amplitude is large the fall in the range of amplitudes common to the two experiments is more rapid than when the initial amplitude is small.

Figure 38 shows this for wire No. 4 when in state II. The initial amplitudes were 1, 4, 7 and 10 degrees per unit length respectively, for the curves 1, 2, 3 and 4. Theoretically the

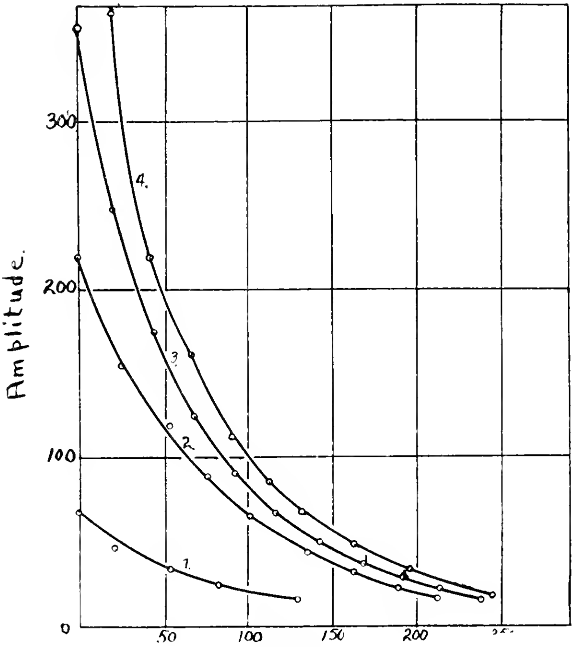

FIG. 38.

curves should be parallel but careful measurements prove that they are not. There is a progressive change in the slopes of the period-amplitude curves, the curves tending to become steeper with the larger initial amplitudes. This is not a new point but has been observed in other wires by Kelvin[8], and by Sieg[9]. We have reasons to suspect that the previous history plays a large part in this effect.

States II and III. The reasons for the peculiar conditions of phosphor-bronze wires now became the object of research. As stated above, curves II and III were the rule while those of type I were the exceptions. The very first tests showed all

[8]Kelvin, Math. and Phys. papers, p. 22.
[9]Loc. cit., p. 6.

wires from No. 1 to No. 7, inclusive, to be in state I. After that, however, this state became exceptional. To illustrate how complicated the changes of states are, the following paragraphs are given.

It has already been stated how wire No. 1 changed from state II into state III during the summer without any treatment. The wire was then vibrated artificially by means of the apparatus shown in figure 27, for 20 minutes at the rate of about 40 complete vibrations per minute. (During this process the pendulum was fixed.) The state was now I and the curve is shown in figure 29 (curve I). After another 30 minutes of rotation the wire was in state III again. Another hour of vibration had no appreciable effect.

The wire was then annealed by 1.2 amperes current in a vessel exhausted to about 3 cm. pressure and under a load of 27 grams. The first condition above was simply a precaution to prevent oxidation. The temperature became so high that the wire softened and allowed its load to fall about 1 cm. to the bottom of the annealing tube. A test now showed the wire to be in state II again. At other times the same process yielded state III.

The same inconsistencies were found in all the wires. There was never any doubt as to the state of the wires because of the magnitude of the effects.

Rates of loss of energy in states II and III. If A_1, A_2, A_3 be the successive amplitudes of vibration, we may say that

$$\text{The Potential Energy at } A_1 = \frac{\mathcal{T} \times A_1}{2}$$

where

$$\mathcal{T} = \frac{A_1 K}{L}$$

or

$$\text{P. E. at } A_1 = \frac{K A_1^2}{L}$$

and

$$\text{P. E. at } A_2 = \frac{K A_2^2}{L}$$

their difference is

$$\frac{K (A_1^2 - A_2^2)}{L}$$

and the rate of loss of energy is

$$\frac{K (A_1^2 - A_2^2)}{TL}$$

The rates of loss of energy were calculated for several of each type of curves. Two of each of types II and III are shown in figure 39. There is seen a tendency for type II to have a more rapid rate of loss than type III. Below an amplitude of 200 degrees (with a 30 cm. suspension), the rates of loss are essen-

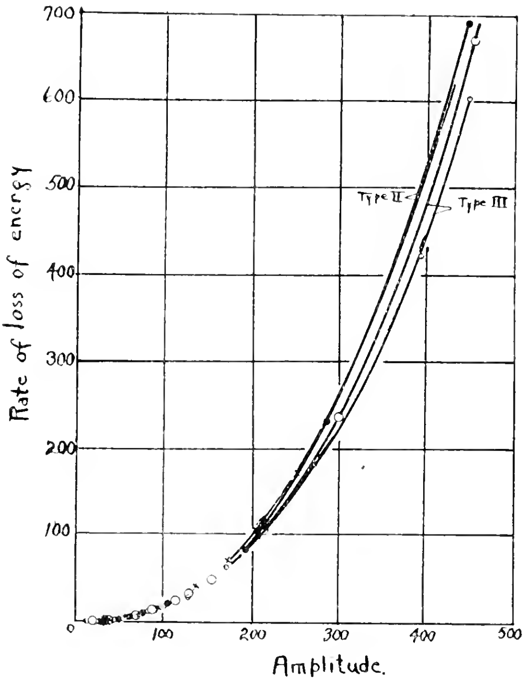

FIG. 39.

tially equal. Table IV shows the calculations for one of each type of curves. It is seen from these data that the difference between the successive angles is quite large and the calculations are thus only approximate. The data should be taken very accurately and the curves plotted on a large scale so that the rates of loss of energy may be compared. Time would not permit a more careful study of this point at this time.

TABLE IV.

Type II. Amplitude	Type II. Rate of Loss	Type III. Amplitude	Type III. Rate of Loss
413	564.1	450	650.5
255	172.4	300	239.5
177	72.2	215	107.5
128	33.8	155	45.9
96	17.3	116	25.6
74	9.3	91	14.2
57	5.5	70	8.3
44	3.1	52	4.3
34	1.8	38	2.1
25	1.3	25	.93
18	.5		

If we now assume that the rates of loss are equal in the two states, for they seem to be nearly so in the smaller amplitudes, we may say,

$$\frac{K'(A_1^2-A_2^2)}{T'L} = \frac{K'(A_1^2-A_2^2)}{LT''}$$

where T' is the steadily increasing period of type III and T'' is the decreasing period of type II. Then T' and T'' are the only variables in the above equation and if the equation is to hold

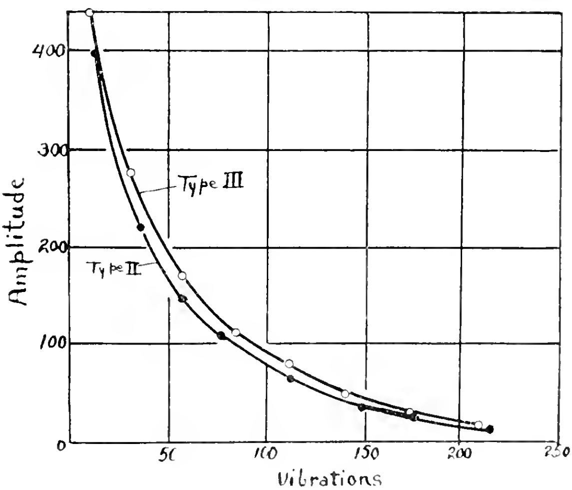

FIG. 10.

true, the value of $(A_1^2-A_2^2)$ must also increase in the left-hand side and decrease in the right-hand side of the equation. Otherwise the equality would be destroyed. Hence for equal falls in amplitude in the two types the loss of energy is smaller in the first than in the second, or we would expect to find that the amplitude-vibration number curves would be different in slope, since one would be damped more rapidly than the other. To see whether or not this reasoning was correct several curves of the two types were compared. In every case the curve of type III fell slightly above the curve of type II. This is shown in figure 40. As we should expect, the two curves tend to coincide again in the small amplitudes. This is easily explained by the fact that the period of type II again increases after the minimum at 4 degrees per cm. length. Again, as we should expect, type I continues below type III throughout the life of vibrations.

Logarithmic decrement. In ordinary damped vibrations the logarithmic decrement is constant and is expressed by log K, Where A_1, A_2, A_3, A_4,...are the successive amplitudes and bear the relation,

$$\frac{A_1}{A_2} \times \frac{A_2}{A_3} \times \frac{A_3}{A_4} \times \frac{A_{n-1}}{A_n} = K^{n-1}$$

$$\frac{A_1}{A^n} = K^{n-1}$$

$$\text{then} \qquad \log K = \frac{\log A_1 - \log A_n}{n\text{-}1}$$

Table V below shows how the log K varies in a sample of wire No. 4. These tables have been compiled for several curves of each type for several diameters of wires and all are found to be very irregular with a general tendency for the log K to fall off in the smaller amplitudes. Thus nothing of value can be learned from the log K curves of the different states. The log K has no real meaning in these cases.

TABLE V.

Wire No. 4 in state II. (Length=8.9 cms.)

Mean Amplitude	Log K
130.5	.0056
88	.0046
65	.0032
47	.0040
34	.0033
26	.0039
20	.0036
14	.0025
11	.0036

The effecting of states II and III. The inconsistencies of the effect of annealing and vibrating the wires were at first difficult to explain. The conditions were evidently very complicated. In annealing, even when the variables of the process, the load, the current and the time of annealing were kept constant, there was no regularity in the results. A very high temperature by a large current would cause one state at one time and another state at another time. The wires were heated to a dull red glow and still the state could not be predicted. Wires Nos. 3 and 4 were then annealed by different currents, to determine whether there were not perhaps definite lower temperatures at which definite states would result. The currents were varied by .1 ampere between the range of .2 ampere up to 1.8 amperes when the wires began to glow. After each annealing, the previous history of the wire was destroyed by the largest current the wire would carry. Still there was no regularity of results.

The slow or sudden cooling of the wires after annealing, gave no clue. At first the time of annealing seemed to have no effect upon the resulting state. Long continued vibrating by the motor usually changed the state but unless the process was long continued nothing could be predicted. It was, however, noted that when the time of artificial vibration was very long state II would usually result. Only one exception to this has been found and that was a sample of wire No. 3, which was not changed from state III in 13.5 hours of continued vibration. The required time to bring about state II was found to be in the neighborhood of 12 hours for wire No. 4. In general the required time is shorter for the smaller wires and longer for the larger wires.

The most recent work has shown that long annealing by a comparatively large current, with the wire supporting a small load, gives state III. Wire No. 4 was annealed by 1.0 ampere while it supported a load of about 25 grams, and in four different trials has always been changed to state III. The same wire under a load of 154 grams was not changed from state II by the same current in 38 hours. This point requires some further investigation before a definite relation of temperature and the resulting state of the wire can be stated. In general, we may say that long annealing with the wire under a small load, and at a comparatively high temperature, causes state III. On the other hand long continued vibration causes state II.

SUMMARY AND CONCLUSION.

The main points of this paper on the elastic properties of phosphor-bronze wire, are:

1. There are three states in which the wires appear.
2. Drawing of the wires has a tendency to increase the effect of a varying period with the amplitude.
3. The magnitude of the period of vibration and the load supported by the wire have no appreciable effect upon the period-amplitude curves.
4. In a given sample of wire with a constant load and period, the number of vibrations executed during a fall of a given number of degrees in amplitude, varies inversely as the length of the suspension. $N x L = K$.
5. The initial amplitude determines to a certain extent the rate of loss of energy of the pendulum.
6. In the larger amplitudes state II has a more rapid rate of loss of energy than state III and their rates tend to become equal in the smaller amplitudes.
7. The amplitude-vibration number curve of state III is gentler in slope than the one of state II but the two coincide in the smaller amplitudes.
8. In general, long continued annealing at a comparatively high temperature brings about state III.
9. Long continued vibration will, in general, bring about state II.

In conclusion we must say that phosphor-bronze wires are certainly not fit for use in delicate suspensions. The elastic peculiarities are too complicated to be corrected for.

While these elastic properties may be typical of this alloy alone, it is reasonable to suspect that other alloys have their distinct peculiarities just as platinum-iridium and these wires were found to have.

I wish to acknowledge my indebtedness to the staff of the Department of Physics for their interest in the problem, and especially to Dr. Sieg for suggesting it, and for his encouragement and assistance during the progress of the work.

State University of Iowa.

University of Iowa.

A NEW METHOD OF IDENTIFYING POLARIZED LIGHT REFLECTED FROM SMALL OPAQUE CRYSTALS.

LEROY D. WELD.

The method is a modification of one used originally by Voigt for the identification of elliptically polarized light. The light under examination passes first through an arrangement of quartz wedges acting as a Babinet compensator, then through a "rotator" consisting of another pair of quartz wedges cut perpen-

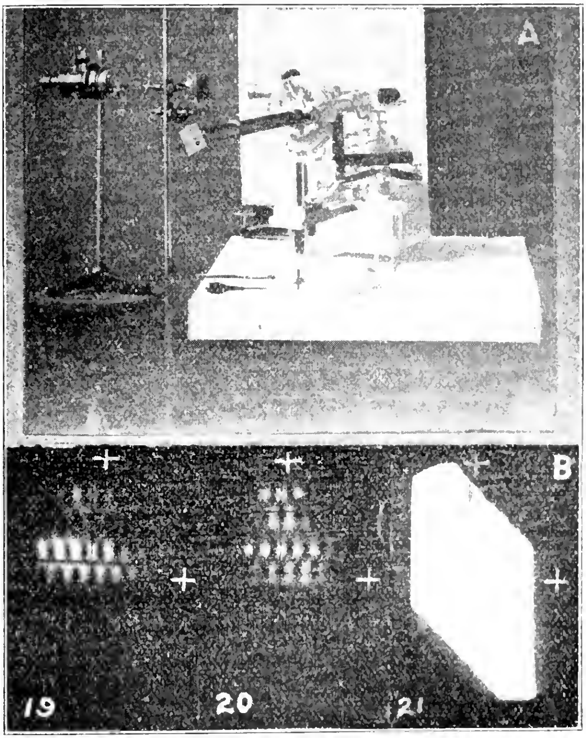

FIG. 41A. View of Apparatus.
FIG. 41B. Typical Spot-Patterns with Selenium (19 and 20), and Comparison Pattern (21).

dicular to the axis, one from right-handed, the other from left-handed quartz: and finally through a large Nicol prism. The result is that the field is filled with rows of black spots in regular arrangement; and from the location of these spots with reference to the cross-hairs, as photographed, the exact character of the elliptic vibration can be readily calculated.

In this particular application, the parallel beam of light is reflected from a small metallic crystal and is very slender, so that only a small portion of the field is illuminated at once. In order to produce the spot pattern, the analyzing apparatus is carried back and forth with a sort of weaving motion, at right angles to the beam, until the whole field is covered. The pattern then appears clearly on the plate, and measurements are easily made upon it. Some excellent plates have been obtained in this manner from very small crystals of selenium. See figure 41.

From such plates, it ought to be possible to settle the question whether metallic crystals are doubly refracting. In fact, the preliminary results would indicate that such is the case with selenium. The research is still in progress.

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WHY HOT WATER PIPES IN HOUSEHOLD PLUMBING BURST MORE FREQUENTLY THAN COLD WATER PIPES.

F. C. BROWN AND WALDEMAR NOLL.

Plumbers often notice that the hot water pipes in a plumbing system that lead to the bathroom or kitchen burst more frequently than the pipes carrying cold water. It is said that the ratio is at least four to one. The "Cold Water" usually freezes so as to lessen the flow of water in the pipes, or to stop the flow altogether, but the freezing seldom bursts the pipes unless the temperature is very low.

In verifying the plumber's observations the exact conditions as they exist in the pipes were not obtained, but some of the essential features were approached by substituting glass test tubes for the pipes. The freezing conditions were simulated by filling one set of tubes with tap water, freshly drawn, and by filling an alternate set of tubes with tap water which had been boiled and then cooled to the temperature of the water in the other tubes. The glass tubes were of especial advantage in that the visible appearance inside the tubes gave valuable information on what was occurring in the respective cases.

The tests carried out fully substantiated the phenomenon that hot water pipes burst more frequently than cold water pipes. On seven different occasions over fifty pairs of tubes were used, filled alternately with boiled and unboiled water, brought to the same temperature. They were placed in the open air when the temperature was below the freezing point. The times of freezing varied from a half hour, or even less, to three or four hours. The tubes were of varying size but most of them were one centimeter in diameter.

Of fifty pairs of tubes used twenty-two pairs burst, and in eighteen pairs the boiled broke before the unboiled, and in four pairs the unboiled broke first.

The observations of the plumbers being verified, the next step was to find an explanation of the phenomenon. One day, when the tubes had been filled with both kinds of water and left standing, it was noticed that the tubes holding the unboiled tap water had their walls covered with air bubbles while the others were perfectly clear. This observation, along with observations made on the drop of temperature, gave some very valuable information toward the explanation of the phenomenon. The temperature drop was read by filling comparatively large tubes with boiled and unboiled water at exactly the same temperature. The temperature was approximately the same until at about zero or a little lower where the unboiled water began to freeze. The boiled water, however, continued to cool until from minus two to minus five degrees centigrade, when it suddenly crystallized into ice, while the temperature again rose to zero.

This difference in freezing probably was due to the fact that air particles, with their impurities, form nuclei where crystallization into ice may set in. In the unboiled water crystallization begins at zero, but in the boiled it is delayed while the water cools to several degrees below zero. Then when it does set in, the water freezes more rigidly into the tube, as the ice forms just as soon in the center as on the outside, which is not the case with unboiled water. This rigid freezing causes greater pressure to be exerted on the walls of the tube, making it harder for the ice to slide away. Then on further expansion of the ice, the tube bursts.

On studying the ice of both kinds of water it was noticed that a white, cloudy core existed in the center. The core was much smaller in the ice from the boiled water. On breaking these tubes in two, this center was found to be slushy and honeycombed, and the whole central portion of the tube filled with air bubbles. Professor Quincke of the University of Heidelberg (Proc. Roy. Soc. Canada 3, p. 24, 1909) explained the presence of the air in the center by the fact that at the boundary line between the ice and the water in a freezing solution a surface tension exists which forces the air and salts away. It is precisely the same action that causes the ice of impure pond water to be purer than the mother liquid.

In studying the drop of temperature we noticed that the boiled water froze just as solid in the center as on the outside when freezing started. In the unboiled water, however, the ice formed on the walls and slowly froze toward the center. Thus in the very act of freezing a core would form in the center of the unboiled water which would not appear so easily in the boiled water. Then the occluded air, as explained above, is forced into this core of the unboiled water. Thus, when the ice freezes toward the center, enough of this central mixture of ice and water is forced away to take up the expansion of the ice. This was proven experimentally. Eleven pairs of tubes were filled alternately with boiled and unboiled water and frozen, and the eleven tubes having the greatest expansion out of the top were noted. Ten of them contained ice of unboiled water, and one of boiled water. In the plumbing system, this slushy center, instead of forcing the column of ice away as in the test tubes, is itself forced toward the terminals of the exposed pipe.

Thus we may say that boiled water freezes nearer to the natural conditions than the unboiled. In other words, the unboiled water would freeze just as quickly as the boiled water if it were air free. or vice versa, the boiled water would freeze like the unboiled if it contained air. The latter was proven experimentally. Twelve tubes were taken, six filled with unboiled water and six filled with boiled water that had been saturated with air. The tubes burst approximately at the same time, as was anticipated.

The air in the freezing of the liquid, as we saw before, separates out and forms little white spots in the ice. This weakens the ice and makes it more mobile, more easily forced away, when pressure, due to further expansion, is exercised upon it, than if it were solid. K. R. Koch (Ann. d. Phys. 41, pp. 709-727, 1913) found the ice containing air bubbles to have a lower elasticity than air-free ice. In other words, air weakens the ice. This weak ice has a lower perpendicular pressure on the walls of the tubes, and, therefore, the probability of the tubes bursting is lessened.

The air in the water also acts as a compressible medium, that is, when the ice expands by freezing. the air is compressed to make room for the expansion of the ice.

Finally to prove that chemical reaction was negligible, boiled and unboiled distilled water, which is practically free from chemical impurities, was set to freeze. Adeney (Phil. Mag. pp. 361, 9, 1905) found that water absorbs air. The boiled water broke the tubes first, as expected. Then the boiled, distilled water was saturated with air and set out together with unboiled water to freeze. The boiled water broke the tubes first.

In summing up the results of the experiments it was concluded that the occluded air effects the difference in bursting. It does this first, by acting as nuclei for crystallization so that ordinary water freezes less solidly than boiled water. Second, by causing the ice to freeze less solidly, especially at the center, until a very low temperature is reached the pressure along the center is relieved by the water and slush flowing away. Third, the air acts as a compressible medium, which relieves the pressure by an unknown amount.

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BIBLIOGRAPHY OF LITERATURE BEARING ON THE LIGHT-SENSITIVENESS OF SELENIUM.

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1818

Berzelius (Schweigg. Journ., 23, pp. 309-344 and 430-484), Discovery, character, compounds, etc.

1826

Seebeck (Pogg., 6, p. 155), Electrification of vitreous Selenium.

Berzelius (Pogg., 7, p. 242), Purification (Pogg., 8, 21), Atomic Weight.

1827

Mitscherlich and Nitzsch (Pogg., 9, 627-630), Selenic acid and salts.

Magnus (Pogg., 14, 328, and 10, p. 491), Solubility in sulphuric acid.

1828

Fischer (Pogg., 12. 153-155), Solubility in sulphuric acid.

Fischer (Pogg., 16, 121), 1829, Solubility in sulphuric acid.

1830

Magnus (Pogg., 20. 165-166), Separation from compounds.

1831

Rose (Pogg., 21, 431), Sulphur, Selenium and Tellurium.

1839

Knox (Trans. Roy. Irish Acad., 19, 149 (1843); or Phil. Mag., Ser. 3, 16, 185), Conductivity of Selenium and other materials.

1840

Regnault (Ann., Ser. 2. Vol. 51), Specific Heat.

Fröbel (Pogg., 49, 590-591), Crystal form of metallic Selenium.

1845

Riess (Pogg. Ann., 64. 50), Electrification of Selenium.

16

1847

Sacc (Ann., Ser. 3, 21, 119-126), Atomic weight.

1848

Schaffgotsch (Journ. pr. Chem., 43. 308-309, also Pogg., 90, 66), Specific gravities.

1849

Erdmann and Marchand (Journ. pr. Chem., 55, 202, 1852), Atomic weight.

1851

Hittorf (Pogg., 84, 214-220), Melting point of the metallic form, transformation between the allotropic forms.

Mitscherlich (Berlin Acad., 409-416; or Ann. (3) 46, 301-313), The red crystalline form of selenium and its properties.

1856

Regnault (Ann., ser. 3, 46, 288-301), Specific heat, general properties, heat of transition.

1857

Oppenheim (J. pr. Chem., 71, 279-282), Separation from tellurium.

Bötger (J. pr. Chem., 71, 512), Decomposition of selenide solutions.

1858

Bettendorf and Wüllner (Pogg. Ann., 138, 26), Specific heats of allotropic modifications.

Mattheissen (Pogg. Ann., 103, 412), The electromotive force of elements.

1859

Dumas (Ann. d. Phys., (3) 55, 186-187), Atomic weight.

Deville and Troost (Compt. Rend., 56, 891), Vapor density.

1860

Uelsmann (Ann. d. Phys., 116, 122), Various compounds.

1863

Deville and Troost (Compt. Rend., 56, 891), Vapor density.

Werther (Journ. pr. Chem., 88, 180-181), Spectrum.

1865

Böttger (J. pr. Chem., 94, 439-440), Separation by dissolving in sodium sulphite solution.

Neumann (Pogg., 126, 123, 1865), Specific heat and specific gravity of metallic form.

Plücker and Hittorf (Phil. Trans., 155, 1-29), Spectrum.

1866

Schneider (Pogg. Ann., 128, 327-334), Solubility in selenious bromide.

1868

Bettendorf and Wüllner (Pogg., 133, 293), Specific heat.

Quincke (Pogg. Ann., 135, 629). Capillary constant.

1869

Fizeau (Compt. Rend., 68, 129, 1125; Pogg. Ann., 138, 26), Coefficient of expansion.

Schultz-Sellack (Berl. Akad., Ber. 745; Pogg., 139, 182), Diathermacy.

Rathke (Journ. pr. Chem., 108, 235-354, 321-356; Ann., 152, 181-220), Analogies between selenium and sulphur.

1871

Sirks (Pogg. Ann., 143, 429-439). Refraction and dispersion of selenium.
(Compt. Rend., 73, 622). Spectrum.

1873

Peterson (Berl. Akad., Ber. 6, 1466). Separation.

Salet (Ann., (4) 28, 47-49), Spectrum.

Sale (Proc. Roy. Soc., 21, 283-289; Pogg. Ann., 150, 333), Conductivity and light effect.

Smith (Am. Journ. Sc., (3) 5, 301), Conductivity and light effect.

1874

Quincke (Wied. Ann., Jubelband. p. 336), The refraction and absorption coefficient of selenium.

Rammelsburg (Pogg. Ann., 152, 151), The modifications of selenium.

Ross (Phil. Mag., 47, 161). The resistance of selenium.

Hilger (Ann. d. Chem., 171, 211). Solubility in sulphuric acid.

1875

Adams (Proc. Roy. Soc., 23, 535; and Pogg. Ann., 159, 622), The action of light on selenium.

(Proc. Roy. Soc., 4, 163; and Pogg. Ann., 159, 629), The action of light on selenium and tellurium.

Rolls (Phot. News, p. 407, 1875). Photometer.

Siemens (Berl. Sitz.-Ber., p. 280; Pogg. Ann., 156, 334). The influence of light on conductivity of selenium.

Siemens (Dinglers Polytech. Journ., 217, 61). Electrical photometer.

1876

Adams and Day (Proc. Roy. Soc., 23, 539), Action of light on selenium.

Draper and Moss (Chem. News, 33, 1 and 203), The action of light on the conductivity of selenium.

Gordon (Jahrs. ber. d. Chem., 121), Action of light on conductivity of selenium.

Siemens (Berl. Akad., Ber., p. 299; and Pogg., 159, 117-141), The effect of light and heat on the conductivity of selenium.

Moss (Chem. News, 33, 1). Conductivity and light-effect.

Adams (Proc. Roy. Soc., 24, 163-164; Pogg. Ann., 159, 629), Conductivity and light-effect.

1877

Braun (Wied. Ann., 1, 95), Conductivity, Ohms law and light-effect.

Forssmann (Wied. Ann., 2, 512-521), The conductivity of selenium.

Siemens (Wied. Ann., 2, 521, 534), The effect of heat and light on conductivity.

Eggoroff (Journ. Russ. phys. Chem. Ges., p. 304), Experiments with the selenium photophone.

1878

Sabine (Phil. Mag., (5) 5, 401-415). Effect of light and heat on the conductivity.

Sabine (Nature, 17, 1878, 512). Action of light on selenium.

Selecq (Beibl. z. d. Ann., 3, 294). The telectroscope.

1879

Perosino (Beibl. z. d. Ann., 3, 656). Telephotography without wires.

Carnelly and Williams (Chem. News, 39, 286). Boiling point.

1880

Brequet (Ann. d. Chim. Phys., 21, 560). Photophone.

Brequet (Compt. Rend., 91, 595). The photophonic experiments of Bell and Tainter.

Bell (Proc. Am. Ass. Sc., 115-136; Ann. Chem. Phys., 31, 399; Electro-tech. Zeits., p. 391). Selenium and the photophone.

Bell (Sill. Am. Journ. Sc., 22, 305). The production and transmission of tones by light.

Bell (Compt. Rend., 91, 726). The use of the photophone for investigation of sun spots.

Blondlot (Compt. Rend., 91, 882). New electrical properties in selenium.

Obach (Nature, 22, 496). Influence of phosphorescent light on selenium.

Linde (Photogr. Archiv., p. 205). Phonograph.

Paiva (Typographie de J. da Silva, Porto, 1880). An electrical telescope using selenium.

Perry and Ayrton (Nature, 21, 589). Seeing by electricity.

Weinhold (Electrtech. Zeits., p. 423). Photophone.

1881

Bellati and Romanese (Beibl. z. d. Ann., 6, 116). The rapidity of change of conductivity by light.

Bidwell (Phil. Mag., 11, 302). The action of temperature on the resistance of selenium.

Bidwell (Chem. News, 43, 105; Nature, 23, 58). Telephotographie and photophon.

Carpenter L. (Nature, 24, 491), The use of the photophone.

Giltay (Nature. 25, 124). An audible photometer.

Kalischer (Rep. d. Phys., 17, 563), Photophon without batteries.

Mercadier (Compt. Rend., 92, 1407, 1881), Effect of temperature on photophonic receivers.

(Compt. Rend., 92, 789). Construction of photophonic receivers. Also p. 705, C. R.

Molera and Cebrian (Engineering, 1881, p. 358), Conical form of selenium cells.

Moser (Soc. Telegr. Engr., 11, May, 1881), The selenium photophon.

Moser (Phil. Mag., 12, 212), The microphonic action of selenium cells.

Sirks (Beibl. z. d. Ann., 5, 526), The change of resistance of selenium.

Spring (Bull. de 'lAcad. des Scienc. de Belg., 2, 88, and Beibl. 5, 854), The coefficient of expansion of selenium.

Thompson, S. P. (Eng., 1881, p. 96; and Phil. Mag., 11, 286), The use of the conical mirror to illuminate selenium.

Thompson, S. P. (Chem. News. 43, p. 43), The photophone.

Tomlinson (Nature, 23, 457), Photophone.

Vidal (Moniteur de la photogr., 1881, p. 11), Selenium photometer.

Bornträger (Ding. pol., J. 242, 55), Preparation of metallic crystals by sublimation.

1882

Troost (Compt. Rend., 94, 1508), Boiling point.

Kienlen (Bull. Belg. Akad., 37, 440). Method of extraction.

1883

Assche (Compt. Rend., 97, 830), A means of isolating heat and light radiations.

Bidwell (Phil. Mag., 15, 31), Resistance of selenium cells.

Fritts (Sill. Am. Journ., 26, 465; and Lum. Electr., 15, 226), Light sensitive selenium cells.

Heschus (Journ. d. Russ. phys. chem. Ges., 1883).

1884

Heschus (Rep. d. Phys., 20, 490), Influence of light on the conductivity of selenium. p. 565, The theory of light sensitiveness. p. 631, The relation between the light intensity and the change of conductivity.

(Journ. d. phys.-chem. Ges., 1884, vol. 15, pp. 123 and 146), Theory of light effect.

Bidwell (Chem. News, 51, 261 and 310). The resistance of selenium and sulphur cells.

Divers and Shimosé (Chem. News, 51, 199), Separation of selenium and tellurium.

1885

Bidwell (Phil. Mag. (5) 20, 178), The sensitiveness to light.

(Chem. News, 52, 191), Light sensitiveness due to selenides.

Clark (Chem. News, 51, 261), The action of light on selenium.

Morize (Compt. Rend., 100, 271), A selenium actinometer.

Siemens (Berl. Sitz. Ber., 8, 147), Concerning the E. M. F. developed by illumination, also C. R. 100, 271.

Fritts (Elect. Rev., Mch. 7, p. 208,'1885), E. M. F. by illumination.

1886

Fabre (Compt. Rend., 103, 53), The heat of crystallization of selenium.

Kalischer (Wied. Ann., 31, 101), The production of E. M. F. by light.

1887

Fabre (Ann. d. phys. u. Chem., (6) 10, 472). Heat of transformation.

Bellati and Lussana (Beibl. z. d. Ann., 11, 818), The influence of light on the heat conductivity.

Kalischer (Wied. Ann., 32, 108), Relation of conductivity to illumination.

Mercadier (Compt. Rend., 105, 801), The selenium radiophonic-receiver of high resistance.

Muthmann (Bull. Belg. Acad., 20, 990), Soluble selenium.

1888

Kalischer (Wied. Ann., 35, 1888, p. 397), Remarks on the experiments of Uljanin and Righi.

Righi (Beibl. z. d. Ann., 12, 683), The E. M. F. of selenium.

Uljanin (Wied. Ann., 34, 241), E. M. F. of selenium in the light.

(Wied. Ann., 35, 836), Reply to Kalischer.

1889

Cornu (Compt. Rend., 108, p. 917 and 1211), The refraction and absorption coefficient of selenium.

Kalischer (Wied. Ann., 37, 528), The E. M. F. of selenium.

Korda (Journ. de phys., 8, 1889, p. 231), Electrical action of light on selenium.

Righi (Wied. Ann., 36, 464), The E. M. F. of selenium.

1890

Liesegang (Photogr. Archiv., 1890, p. 302), Photophon.

Muthmann (Zeits, f. Kryst., 17, 336), Crystallographic studies of certain modifications of sulphur and selenium.

1891

Bidwell (Electrician, 26, 213; Phil. Mag., 31, 250), Several studies with selenium cells.

Liesegang (1 Auflag. Ed. Liesegang), The problem of seeing at a distance electrically.

Minchin (Electrician, 26, p. 361; Phil. Mag., 31, 207), Experiments with photo-electricity.

Peterson (Zeits. f. Phys. Chem., 8, 601), The allotropic forms of several elements.

Muthmann (Zeits. phys. chem., 8, 396-397), Isomorphism with sulphur.

Retgers (Zeits. phys. Chem., 8, 72), Isomorphism of Selenium, Sulphur and Tellurium.

1892

Minchin (Astron. and Astroph., 108, 702), photo-electric cells.

1893

Minchin (Lum. e'lectr., 48, 543), Photo-electric cells.

1894

Marjorana (Rend. R. Acc. d. Linc., 3, 183; and Beibl., 18, 930). The rapidity of light action in selenium.

1895

Bidwell (Phil. Mag., 40, 233), The electrical properties of selenium.

Minchin (Proc. Roy. Soc., 58, 142), The use of selenium in photometry.

Bidwell (Mechaniker, 1895, p. 232), Telephotography.

1896

Giltay (Nature, 54, 109), Roentgen Rays and the resistance of selenium.

Marjorana (Beibl. z. d. Ann., 20, 558), Action of a periodically interrupted light beam on selenium.

1897

Schmidt (Wied. Ann., 62, 407), Electrical phenomena in selenium and flourspar.

Tammann (Wied. Ann., 62, 280), Two melting points.

1898

Agostini (Forts, d. phys., 11, 592), The action of electro-magnetic waves on selenium.

Dussaud (Compt. Rend., 128, 1132), Transmission of varying light intensities by electric wires.

Lehner (Journ. Am. Chem., S, 20, 555), Atomic weight.

1899

Dussaud (Compt. Rend., 128, 171), Transmission of tones by ultra violet light.

Liesegang (Edition 2, pamphlet on the problem of seeing at a distance).

Perreau (Compt. Rend., 129, 956), Effect of X rays on the resistance of selenium.

1900

Clausen and v. Bronk (New phenomena in the field of Physics; self published, Berlin).

Himstedt (Ann. d. Phys., 4, 531), Some experiments with Becquerel and X rays.

Saunders (Journ. Phys. Chem., 4, p. 423), The allotropic forms of selenium.

1901

Bloch (Compt. Rend., 132, 914), Action of Radium rays on selenium.

Giltay (Phys. Zeits., 1901, p. 675), Apparatus for the demonstration of the light-sensitiveness of selenium.

Giltay (Mechaniker. 1901, p. 243). Apparatus for demonstrating the photophon.

Massini (Eclair. e'lectr., 29, p. 68), The effect of electromagnetic waves on the resistance of selenium.

Ruhmer (Phys. Zeits., 2, p. 325), The talking arc with selenium.

Ruhmer (Phys. Zeits., 2, 498), The photographone.

Ruhmer (Mechaniker, 9, 468 and 2), Simons photophone.

Ruhmer (Mechaniker, 9, 41), The preparation of light sensitive cells. (9, p. 88), The talking arc and light telephony.

Ruhmer (Mechaniker, 9, 1901, p. 13), Seeing at a distance, etc.

Simon (Phys. Zeits., 2, p. 253), Light telephony with the speaking arc.

1902

Coblyn (Compt. Rend., 135, 684), Seeing at a distance electrically.

Korn (München Ber., 37, 39), An experiment with electrical photography at a distance.

Korn (Electrotech. Zeits., 23, 454), An apparatus for distance photography.

Pochettino (Beibl. z. d. Ann., 27, 854), The influence of low temperatures on the resistance of selenium and the resistance change by light.

Ries, Chr. (Dissertation, Erlangen, 1902), The electrical behavior of metallic selenium with light and temperature changes.

Ruhmer (Elektrotech. Zeits., 23, 859), Light telephony.

Ruhmer (Phys. Zeits., 3, 468). The light-sensitiveness and fatigue of selenium cells.

Ruhmer (Phys. Zeits., 3, 532). Cylindrical selenium cells.

Ruhmer (Tech. Rundsch., 1902, 339) (Elek. chem. Zeits., 9, 98). A new light-sensitive cell.

Ruhmer (Mechaniker, 1902, p. 185), The telautograph.

Ruhmer (Monograph pub. by "Der Mechaniker"), Selenium and its application, with special reference to wireless telephony.

Ruhmer (Zeits. f. Phys. u. Chem. Unt., 15, 126), Apparatus for demonstrating light action in selenium.

Simon Th. and Reich (Phys. Zeits., 3, 278), Musical arcs and light-telephony.

Wood (Phil. Mag., [6], Vol. 3, p. 607), The refraction and absorption coefficients of selenium.

1903

Anzel (Zeits. f. Elektrochem., 9, 695), The change of resistance by light in other materials than selenium.

Aubel (Compt. Rend., 136, 1189; and Phys. Zeits., 4, 808). The action of ozone-treated bodies on the conductivity of selenium.

Aubel (Compt. Rend., 136, 929, and Phys. Zeits., 4, 807). The action of radioactive bodies on the conductivity of selenium.

Giltay (Phys. Zeits., 4, 287), Improved apparatus for demonstrating the light-sensitiveness of selenium.

Griffiths (Compt. Rend., 137, 647), Change of resistance of selenium under the action of certain substances.

Hammer (Trans. Am. Inst. Electr. Eng., 20, 541), The properties and uses of selenium.

Heschus (Journ. d. Russ. phys.-chem. Ges., 35, 661), Relation of electrical conduction to illumination.

Hopius (Beibl. z. d. Ann., 28, 723), Dependence of the conductivity on the degree of illumination.

Korn (Compt. Rend., 138, 1190), Picture Telegraphy.

Marc (Zeits. f. anorg. Chemie, 37, 459), The effect of light and temperature on selenium.

Nutting (Phys. Zeits., 4, 201), The reflection coefficient of selenium.

Ruhmer (Mechaniker, 11, 265), New Selenium apparatus.

1904

Amaduzzi (Phys. Zeits., 5, 647), Selenium.

Berndt (Mechaniker, 1904, p. 97), Selenium cells on carbon.

Berndt (Phys. Zeits., 5, 121), Some observations on selenium cells.

Berndt (Phys. Zeits., 5, 289), the action of selenium cells on a photographic plate.

Berthier (Beibl. z. d. Ann., 28, 876), The photo-electric properties of selenium.

Biltz (Nachr. d. Gott. Wiss. Ges., 1904, p. 18).

Chabot (Phys. Zeits., 5, 1904, 103 and 168), New rays or a new emanation. Also Phys. Zeits., 5, 517 and 584.

Agostini (Phys. Zeits., 5, 121), The electrical properties of selenium.

Davis (Nature, 70, 506), Is selenium radioactive.

Korn (Phys. Zeits., 5, 113), New sending and receiving apparatus for distance photography.

Korn (Phys. Zeits., 5, 164), Receiving apparatus for distance photography.

Korn (Monograph printed by S. Hirzel press, Leipzig), Electrical distance photography and similar things.

Nisco (Eclair. e'ectric, 30, 1904), Photometer.

Pfund (Phil. Mag., 7, 26), Studies with selenium cells.

Reiff (Mechaniker, 1904, p. 75, 86 and 100), Transmission of pictures and writing by the Korn method.

Ruhmer (Elektrotech. Zeits., 25, 1021), Selenium and its technical applications.

Stephan (Beibl. z. d. Ann., 28, 447). Construction and theory of distance photography.

1905.

Aichi and Tanakadate (Beibl. z. d. Ann., 29, 997), The influence of temperature on the conductivity of selenium.

Brown (Phys. Rev., 20, 185), The effect of pressure on the resistance of selenium.

Bloch (Le Radium, 2, pp. 323-328, and 363-370), The electrical conductivity of selenium.

Carpini (Phys. Zeits., 7, 306), The photoelectric effect in selenium.

Chabot (Phys. Zeits., 6, 37 and 619), New rays or a new emanation.

Coste (Compt. Rend., 141, 715), The electrical conductivity of selenium.

Courvoisier (Astrom. Nachr., 167, 218), The use of selenium cells for making secondary contacts with pendulum.

Giltay (Mechaniker, 1905, p. 280), New forms of selenium cells.

Giltay (Elektrotechn. Zeits., 26, 313), Selenium cells in vacuum.

Heschus (Phys. Zeits., 7, 163), The light-sensitiveness of selenium.

Korn (Elektrotechn. Zeits., 26, 1131), Electrical distance photography.

Ruhmer (Mechaniker, 1905, p. 280), Reply to Giltay.

Ruhmer (Mechaniker, 1905, p. 252), New selenium cells.

Weidert (Ann. d. Phys., 18, 1905, 811), The effect of illumination on the thermo-electric power of selenium.

Wulf and Lucas (Phys. Zeits., 6, 838), The use of selenium cells to determine the time of total eclipse of the sun.

Guilleminot (Arch. Electr. Med. Expt., 13, 243), The action of X rays on selenium.

Guthe (Monthly Weather Rev., 34, 223, 1906), Photoelectric properties of selenium cells.

Raupp (Journ. Gas. Illum., 49, 603), Selenium and its application to gas technology.

Korn (Compt. Rend., 143, 892). An apparatus for measuring the inertia of selenium cells.

Berndt (Weltall, Berlin, 6, 210), Making and mounting of selenium cells.

1906.

Bronk (Phys. Zeits., 7, 281, and p. 431), Announcement on the selenium cells.

Coste (Beibl. z. d. Ann. d. Phys., 32, 96), The electrical conductivity of selenium.

Giltay (Beibl. z. d. Ann. d. Phys., 31, 845), The use of selenium cells in double telephony.

Marc (Zeits. f. Anorg. Chem., 48, 393), The effect of light.

Marc (Ber. d. Deutsch. Chem. Ges., 39, 697), Knowledge about the allotropic forms of selenium.

Pochettino and Trabacchi (Beibl. z. d. Ann., 32, 93), The effect of alternating currents on selenium.

Reinganum (Phys. Zeits., 7, 430), A new form of selenium cells.

Ruhmer (Phys. Zeits., 7, 430), Announcement on selenium cells.

Schrott (Phys. Zeits., 8, 42), The effect of heat and light on the allotropic forms of selenium.

Stephan (Mechaniker, 14, 159 and 173), Construction of a distance photography machine.

Torda (Electrician, 56, 1042), Selenium photometer.

Vogler (Mechaniker, 14, 147), A new arrangement of selenium cells.

1907.

Bidwell (Nature, 76, 444), Practical telephotography.

Bidwell (Nature, 77, 222), The photoelectric properties of selenium.

Brown (Phys. Rev., 25, 505), The effect of radium rays on selenium.

Glatzel (Deutsch. Mechan. Zeit., 18, and Verkehrstechn. Woche, 1907, 45), Selenium and its use in distance photography.

Haub (Mechaniker, p. 75), A new selenium photometer.

Jaeger (Proc. Amsterdam Akad., 9, 809, 1907; and Zeits. f. Krist., 44, p. 45), A comparison of light-sensitiveness of selenium and natural crystals of antimonite.

Korn (Phys. Zeits., 8, 18, 19). A light relay.

Korn (Phys. Zeits., 8, 118), A new method of distance photography.

Korn (Elektrotech. Zeits., 33). Picture transmission between München and Berlin.

Korn (Zeits. f. Schwachstrom, p. 463), Review of picture transmission.

Korn (Ed. 2, of monograph on picture transmission, published S. Hirzel, Leipsig).

Marc (Zeits. f. Anorg. Chem., 53, 298), the effect of light and temperature on selenium.

Marc (Monograph on the physical-chemical properties of metallic selenium. Pub. by Leopold Voss, Hamburg).

Minchin (Nature, 77, 173). The photoelectric properties of selenium.

Moss (Nature, 77, 198), The photoelectric properties of selenium.

Nisco (Zeits. f. Schwachstrom, 1907, p. 253). Seeing at a distance by means of electricity.

Niewenglowski (Science au XX Sie'cle, 5, pp. 9-11). The transmission of photographs.

Presser (Electrotechn. Zeits., 1907, p. 560), A selenium photometer.

Pochettino and Trabacchi (Beibl. z. d. Ann. d. Phys., 31, 1128), The electrical properties of selenium.

Reinganum (Phys. Zeits., 8, p. 293 and 392). A correction on electrolytic selenium cells.

Sperling (Dissertation (Goettingen) on selenium cells. Also Ber. d. Ober. Ges. fur nat. u. heilkunde, N. S. 2, 73).

Wiedhaas (Zeits. f. Phys. u. Chem. Unterr., 20, 93). Experiments for demonstrating the light telephone.

Will (Elektrotechn. Anz., 24, 115, 127 and 141). Review of distance photography.

Stebbins and Brown (Astro. Phys. Journ., 26, pp. 336-340), A determination of the moon's light with a selenium photometer.

Wertheim-Salomonson (Verh. d. Roentgenes, 3, 96-106), The action of X rays on selenium.

1908.

Athanasiadias (Ann. d. Phys., (4) 25, 92; and vol. 27, 890), The relation between illumination and conductivity.

Athanasiadias (Ann. d. Phys., (4) 27, pp. 890-891), The action of X rays on selenium.

Brown and Stebbins (Phys. Rev., 26, pp. 273-293), Studies on electrical resistance of selenium.

Grippenberg (Phys. Zeits., 9, 519), The use of selenium vapor in coating selenium cells.

Korn (Natw. Runds. Braunschweig., 23, 521), New results with telautagraph.

Kohl (Zts. f. Phys. Chem. Unterr., 21, 142), Demonstration apparatus for Korn's distance photography.

Merritt (Phys. Rev., 27, 367), The recovery of selenium from light.

Minchin (Proc. Roy. Soc., A. 81, pp. 9-21), Seleno-aluminum bridges.

Minchin (Nature, 77, p. 198 and 222; also Elect. Rev., 52, 172), The action of mercury vapor on selenium.

Ries, Chr. (Phys. Zeits., 9, 164), Light sensitiveness of selenium.

Ries (Phys. Zeits., 9, 228), Properties of selenium.

Ries (Phys. Zeits., 9, 569), Influence of moisture on the electrical properties of selenium.

Ries, Chr. (Monograph published by the "Mechaniker"), The electrical properties of selenium and its applications.

Stebbins (Astro. Phys. Journ., 27, 183), The color sensibility of different selenium cells.

Zemplin (Potf. Ternt. Kozl., Budapest, 40, 68-70), Action of light on electrical behavior of selenium.

1909.

Chiavini (Rend. R. Acc. dei. Linc, 18, 246), The nature of light action in selenium.

Pfund (Phys. Rev., 28, 324; and Phys. Zeits., 10, 340), The electrical and optical properties of selenium.

Korn (Phys. Zeits., 10, 793), The fatigue of selenium cells.

Grippenberg (Phys. Zeits., 10, 957), The crystallization of selenium plates.

Kruyt (Zeits. f. Anorg. Chem., 64, 305), Dynamic allotropie of selenium.

Montén (Doctor's dissertation—Uppsala, 1909; Arkiv. f. Math., Ast., o. Fysk, vol. 44, pp. 1-6), The influence of pressure on the electrical conductivity of selenium and silver sulphide.

McDowell (Phys. Rev., 29, pp. 1-35), Some electrical properties of selenium.

Ries (Phys. Zeits., 10, 54), The use of selenium vapor for producing light sensitive cells.

Ries (Phys. Zeits., 10, 534), The electrical properties of selenium and the practical applications.

Ruhmer (Monograph pub. by "Mechaniker" press), On wireless telephony.

Ruhmer (Catalog of selenium accessories).

Wigang (Ann. d. Phys., 29, 1-32), Light action in sulphur.

1910.

Baker (Electr. World, 1910, p. 1079), Use of selenium in photo-telegraphy.

Brown (Electr. Rev., 57, 1178, Phys. Zeits., 11, 482), A new light electric property in selenium.

Brown (Phys. Zeits., 11, 481), Selenium cells of high sensibility.

Amaduzzi (Rend. Acad. Bologne, 16, Jan. 19, 1910), The cause of the light-sensitiveness of selenium.

Giltay (Phys. Zeits., 11, p. 419), Selenium cells with high response to light.

Grippenberg (Phys. Zeits., 11, 132-133), Selenium cells of high response to light.

Hammer (Electr. Rev., 56, 905), Selenium cells.

McDowell (Phys. Rev., 30, 474-484), Some electrical properties of selenium.

Luterbacher (Ann. d. Phys., 33, 1392-1412), The influence of E. M. F. on the resistance of selenium.

Meier (Ann. d. Phys., 31, 1910, p. 1017), Dispersion and absorption of light by selenium.

Stebbins (Astro. Phys. Journ., 32, pp. 125-214), The measurement of the light of the stars with a selenium photometer.

Stebbins (Astro. Phys. Journ., 32, 179-182), The brightness of Halley's comet by a selenium photometer.

Pelabon (Compt. Rendus, 151, pp. 641-644), Cells of antimony and antimony selenide.

1911.

Brown (Phys. Rev., 33, 1-26), The nature of light action in selenium.

Brown (Phys. Rev., 33, 403-419), The recovery of the Giltay selenium cell and the nature of light action in selenium.

Brown (Transit, 16, 61), The electrical properties of selenium and their applications.

Crum (The Elect. Rev. and West. Elect., 58, 433), The electrical properties of selenium.

Glatzel (Phys. Zeits., 12, p. 480, 570 and 1169). The fatigue of selenium cells.

Crum (Phys. Rev., 33, 538-548). Light negative selenium.

Pochettino (Sc. Ab., 14, p. 322), Sensitiveness of selenium preparations.

Ries (Ann. d. Phys., 36, 1055), The cause of the light-sensitiveness of selenium. (Phys. Zeits., 12, 480, 522.)

Ries (Phys. Zeits., 12, 529). The effect of voltage on the resistance of selenium.

Ries (Ann. d. Phys., 36, 1055-1065), The potential effect in selenium and antimonite.

Stebbins (Astro. Phys. Journ., 33, 395), The radiation of the companion of Algol.

Stebbins (Astro. Phys. Journ., 34, 105-130). The discovery of eclipsing variable stars.

1912.

Amaduzzi (Phys. Zeits., 13, 165), The Hallwachs effects in selenium.

Fournier d'Albe (Proc. Roy. Soc., 86, pp. 453-461), The variation of resistance with voltage.

Fournier d'Albe (Proc. Roy. Soc., 13, 942), Application of selenium to seeing, the Optophone.

Brown (Phys. Zeits., 13, 689; and Proc. Iowa Acad. Sci., 1912), The effect of abrasion on the electrical conductivity of selenium.

Brown (Phys. Rev., 34, 403), The effective depth of penetration of selenium by light.

Glatzel (Verh. d. D. Phys. Ges., 14, 607-623), Light sensitiveness of selenium.

Korn and Glatzel (Hand. d. Phototel. u. Teleautogr.), The light sensitiveness of selenium.

Grippenberg (Phys. Zeits., 13, 161 and 168), Selenium plates.

Kaempf (Phys. Zeits., 13, 689), Saturation currents in selenium.

Olie and Kruyt (Sc. Abs., 15, abs. 903, 1912), Photo-electric properties of antimonite.

Pfund (Phys. Rev., 34, 371-380; and Phys. Zeits., 13, 507), The application of selenium cells to photometry.

Pochettino (N. Cim., (6) 4, 189-203), The cause of the light-sensitiveness of selenium.

Stebbins (Astro. Nachr., 192, 190-194), The light variation of Ursa Minor.

Zoltan (Phys. Zeits., 13, 1912), The Hallwachs effect in selenium.

Grippenberg (Phys. Zeits., 13, 686), Selenium cells of high sensibility.

1913.

Fournier d'Albe (The Electrician, 72, 102; and Sc. Am., 93, 467), The type-reading optophone.

Fournier d'Albe (Phys. Zeits., 14, 1306), The smallest quantity of light that can be proved.

Brown (Phys. Rev., (2) 1, 237), A method of production of light-negative selenium.

Brown (Proc. Iowa Acad. Sci., 20, 261), The similarity of electrical properties in selenium and crystal contacts.

Brown (Electr. Rev., 62, 104), The electrical properties of selenium.

Brown and Sieg (Phys. Rev., N. S., 2, 487-493), The sensibility curves for selenium.

Grippenberg (Phys. Zeits., 14, 123 and 124), The refractive index of crystalline selenium.

Guilleminot (Compt. Rend., 156, 1155), The action of X rays on selenium.

Nicholson (Phys. Zeits., 14, 1213; and Phys. Rev., Jan., 1914), Electron theory of light-sensitiveness.

Pigulewski (Beibl. z. d. Ann., 37, 72), The action of light on the conductivity of sulphur.

Ries (Zeits. f. Feinmechanik. 21, 61-62), Noteworthy properties of selenium cells.

Ries (Zeits. f. Feinmech., 21, 5-7), Influence of potential and previous illumination on the fatigue of selenium.

Ries (Monograph on selenium and its application. 189 pp. Beibl., 33, p. 627).

Stebbins (Pop. Astro., 21, 1-9), The period and variation of Alpha Orionis.

Brown (Phys. Rev. N. S., 2, p. 153), The action of mercury vapor on selenium.

Brown and Sieg (Phys. Rev., N. S., 2, p. 487), A second paper on the wave-length sensibility curves of selenium cells.

1914.

Brown (Phys. Rev., N. S., 4, 85-98), Isolated crystals of metallic selenium and some of their physical properties.

Brown and Sieg (Phil. Mag., (6) 28, 497-508), The seat of light-action in selenium and some new properties in matter.

Brown and Sieg (Phys. Rev., N. S., 4, 48-61). Wave length-sensibility and their significance.

Sieg and Brown (Proc. Iowa Acad. Sci., 21, 259). The adaptation of selenium to the measurement of energy too small to be measured by other devices.

Sieg and Brown (Phys. Rev., 4, 507-516). Wave length-sensibility curves for the crystals of selenium.

Dieterich (Phys. Rev., N. S., 4, 467-476). Influence of annealing on the characteristics of light-sensitive selenium.

Dieterich (Iowa Acad. Sci., 21, 257). Notes on the construction of selenium bridges.

Foersterling and Friedericks (Ann. d. Phys., 43, 1227). The optical constants of metallic selenium.

Grantham (Phys. Rev., N. S., 4, 255-266). The time factor in the evaluation of selenium resistance.

Del Regno (Sc. Abs., 18, 140). The nature of the photo-electric phenomena shown by selenium.

Grippenberg (Phys. Zeits., 15, 462). The depth of light action in selenium.

Jaenichen (74 pp. Monograph on illumination measurements by selenium. pub. by "Mechaniker" Press). Zeits. f. Feinmech. Press.

Pelabon (Compt. Rend., 158. 1669 and 1897). Thermo-electric power of selenium alloys.

Stebbins (Astro. Phys. Journ., 39, 459-483). Photometric tests of spectroscopic binaries.

Schmidt (Ann. d. Phys., 44. 477-496), The actino-dielectric effect in sulphur.

Tyndall and White (Phil. Mag., 27. 370; and Phys. Zeits., 15, 154). Properties of selenium blocks.

Vonwiller (Engineering. 98, 611). Photoelectric effect in selenium.

(Compt. Rend., 159. 41-43). Influence of tellurium on the sensitiveness of selenium.

1915

Brown (Phys. Rev., N. S., 5, 74-75). Some fundamental photo-electric relations in selenium.

Brown (Phys. Rev., N. S., 167-175), Physical properties of selenium.

Sieg and Brown (Phys. Rev., N. S., 5, 65-67), Wave length-sensibility curves for crystals of selenium.

Brown (Phys. Rev., N. S., 5, 236), The isolation of crystals of the second and fifth systems.

Brown (Phys. Rev., N. S., 5, 395-403), The nature of electric conduction in selenium, based on recovery experiments.

Brown (Phys. Rev., N. S., 5, 404, 411), The nature of the transmitted light action in selenium.

Elliott (Phys. Rev., N. S., 5, 53-64), The light-sensibility of selenium and stibnite.

Guilleminot (Sc. Ab., 18, 524), The use of selenium in measuring the intensity of X rays.

Meissner (Electr. Rev., 66, 288), The applications of selenium—the selenium dog.

Meissner (Purdue Eng. Rev., 15, 34), Selectivity in torpedo control.

Sieg (Phys. Rev., N. S., 6, 213-218), The heat conductivity of selenium.

Dodd (Proc. Iowa Acad. Sci., 22, 307), The absence of absorption or liberation of electrons in passing from conducting to non-conducting state. Also Phys. Rev., 1916.

Brown (Proc. Iowa Acad. Sci., 22, 317), The crystal Phonopticon to enable the blind to read the printed page.

Dodd (Sc. Am., 93, p. 138, Aug. 14, 1915), The mechanical Eye. The crystal Phonopticon.

d'Albe (Sc. Am., 93, 467), Same ref. previously. A comparative estimate of the merits of the above.

Stebbins (Astro. Phys. Journ., 42, 143), The eclipsing variable star delta Orionis.

Voltz (Phys. Zeits., 16, 209 and 308), The application of selenium to the measurement of X ray intensities.

Voltz and Furstencon (Phys. Zeits., 16, 276), Measurement of X ray intensities with selenium.

Dieterich, E. O. (Thesis, University of Iowa, 1916).

Dieterich, Kathryn Johnston, (Phys. Rev.)

1916.

Editorial (Outlook for Blind, Summer number, 1915), A copy of Dodd's article in Scientific Am., Aug., 1914.

Editorials (World of the Blind, Oct., Nov., Dec. and Jan. numbers).

Editorial (Century Magazine, Jan., 1916), Seeing by hearing.

Editorial (The Outlook, Jan. 12, 1916), A mechanical eye.

Editorial (Popular Mechanics, Nov., 1915, p. 644), Blind read by sound. Illustrated.

Editorial (Popular Sc. Monthly and Worlds' Advance, Nov., 1915, p. 570), Seeing with your ears.

Editorial (Illustrated World, Nov., 1915, p. 374), Seeing with ears.

Editorials and short articles in many other magazines and papers.

Dieterich, Kathryn J. (Phys. Rev., N. S., 7, p. 551), The effect of temperature on the resistance, the light sensitiveness of selenium crystals.

Dieterich, E. O. (Phys. Rev., N. S., 8, p. 191), The effect of temperature on the light sensibility curves of different types of selenium cells.

Flowers, John B. (Proc. Inst. Elect. Eng., 35, pp. 183, 201; Elect. Experiment, Apr., 1916, Use of selenium in voice controlled phonographic alphabet.

Flowers, John B. (Sc. Am., Mch. 25, vol. 114, 1916, p. 323), A typewriter that copies what it sees.

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A SHEEP'S BRAIN WITHOUT A CORPUS CALLOSUM.

H. A. SCULLEN.

The brain in question was one from a shipment of dissecting material purchased from the Western Biological Supply Company of Omaha, Nebraska.

It will be seen from the illustration that the entire Corpus callosum and the posterior two-thirds of the Fornix are lacking. Lying between the membranes which form the only wall between the Diacoele and the Paracoele may be seen a slender cord of alba nearly round and about one-fourth of a millimeter in diameter. The connection of this cord seems to be such that it should be considered Fornix and not Corpus callosum. The remaining commissures and all other parts of the brain seem to be normal.

The author has had occasion to examine between two and three hundred sheep brains in the past four years and to date no other abnormality has been noted. So far as is known no other similar abnormality has been reported.

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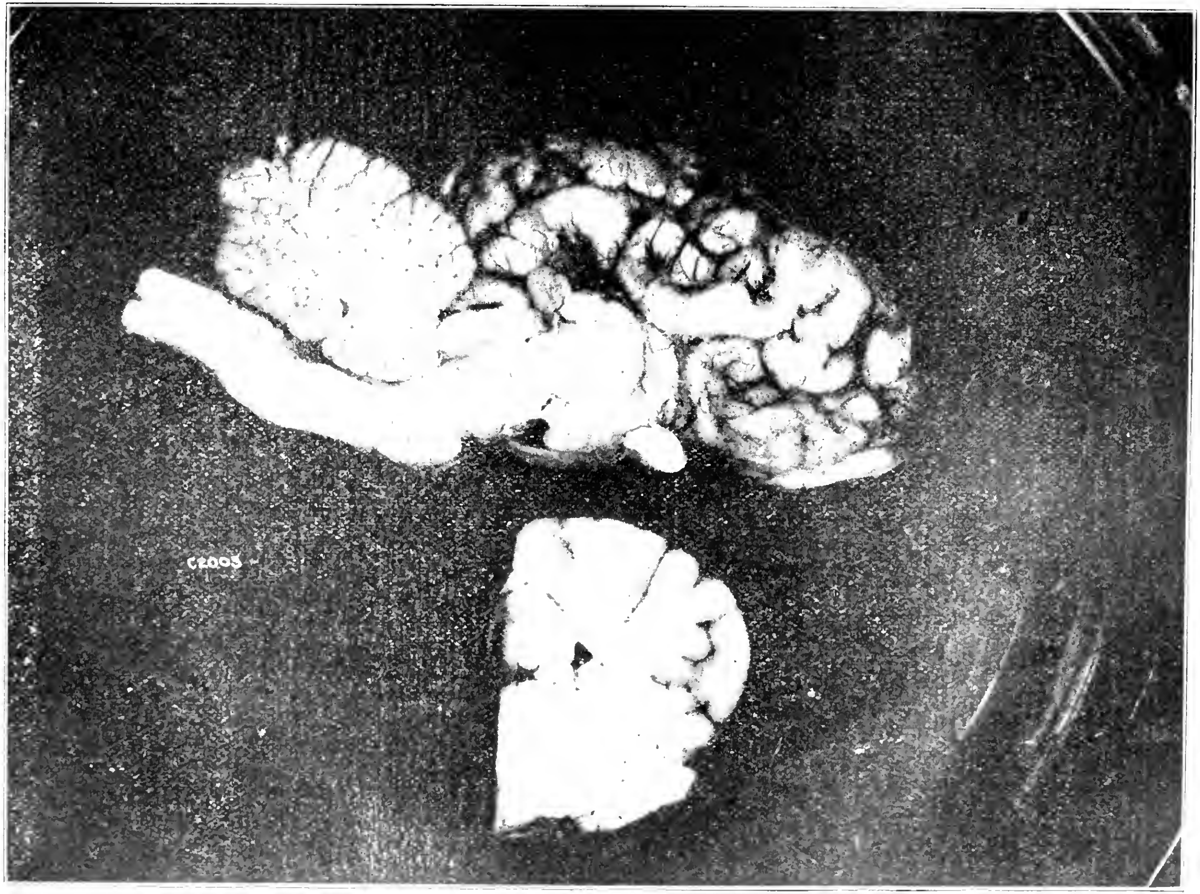
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THE WHITE ADMIRAL OR BANDED PURPLE BUTTERFLY IN IOWA.

B. O. WOLDEN.

During the early part of the summer of 1914 a butterfly was observed around the writer's home, which was identified at the time as *Basilarchia arthemis.* As there seems to be no previous record of this butterfly having been collected in Iowa a brief note, recording the fact, might not be out of place and might be of interest to students of the Lepidoptera of Iowa.

I did not realize at the time that Iowa is not within the published range of this species or that its occurrence here was anything unusual and as I was not collecting butterflies the specimen was not caught. At first I thought there were several of these butterflies but perhaps it was only one as only one was seen at a time. At any rate I saw it several times and had good opportunity to compare it with Comstock's figure of the species. Later in the summer I saw again what I thought perhaps was the same specimen but with torn and ragged wings and faded color. According to Comstocks' figures there is no doubt but that it was the form *lamina* as it had well defined bands on the hind wings, but Holland figures the form *proserpina* also with rather distinct white bands on the hind wings.

No specimen was observed during the summer of 1915 but then there were few butterflies of any kind, at least till the latter part of the summer. It is to be hoped that during the next season specimens can be found, to verify this record.

WALLINGFORD.

AN HERMAPHRODITIC CRAYFISH OF THE SPECIES *CAMBARUS (FAXONIUS) OBSCURUS* HAGEN.

I. L. RESSLER.

Recently, in the course of my work in the laboratory, an abnormally developed crayfish was brought to my attention. This animal had present both male and female characters. The length of this apparent hermaphorite is 77mm., somewhat smaller than the average for this group.

There is a great variation in the general appearance as compared to the normal creature. It has the characteristic broad abdomen of the female. The fifth pereipod alone shows no variation, containing the genital opening in the coxopodite as found in the normal male. The third pereipod has no genital opening. This would seemingly make it a male appendage were it not for the fact that the clasper is not present on the ischiopodite. Between the coxopodites of the fourth pair of pereipods is found the annulus ventralis, common only to females. The first pleopods are characteristic of the male. They are, however, somewhat shorter and stouter than the normal first pleopods, and extend cephalad only as far as the anterior side of the fifth pereipods. The second pleopods are essentially male structures, although not so prominent. (See figure 42, A and B.

The above description shows that the specimen bears, exeternally, markings characteristic of both the male and female. The internal organs of reproduction are equally interesting. The sperm duct arises apparently from a pair of very small ovaries which are situated in a position corresponding to that of the anterior lobes of the testes. The sperm duct itself is normal in every respect and opens to the exterior through the coxopodite of the fifth pereipod. The posterior lobe of the testes is present, extending as far caudad as the first abdominal segment, between the lobes of the liver.

There are several cases on record where hermaphroditism has been described. One of the above species has been described as follows: "The specimen (55 mm. long) has the characters of a female in the shape of the chelae and the absence of hooks on the pereipods. The male genital opening is in the coxopodite of the fifth pereipod, and the first pleopod is of the male type, although small. The second pleopods are of the male type." This specimen was regarded, according to the sexual orifice and the copulatory organs, as a male with female characters.

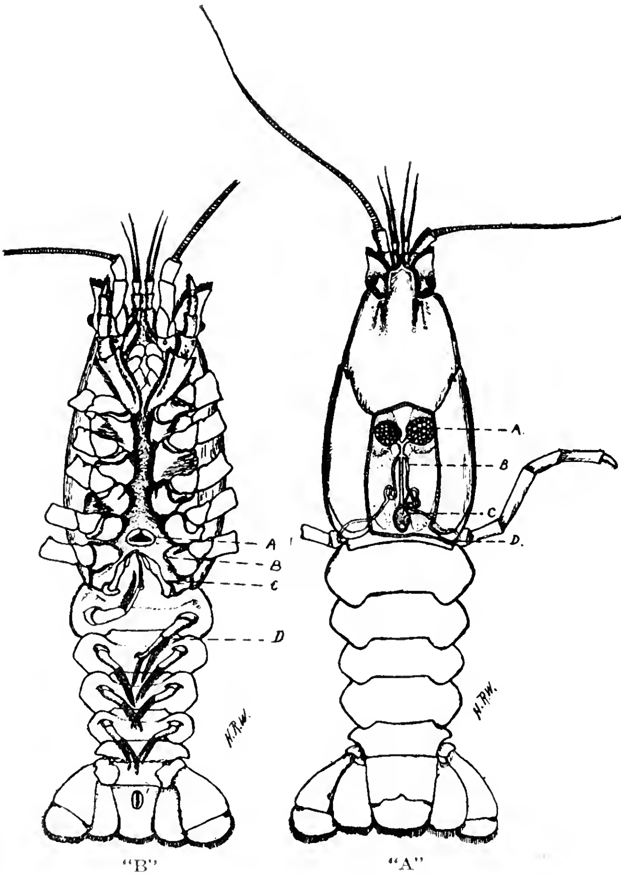

Fig. 42.

A. Dorsal view of crayfish showing abnormal organs. Note the absence of the anterior lobes of the testes. A, small ovaries; B, Sperm duct; C, Posterior lobe of the testes; D, opening of the sperm duct in the coxopodite of the fifth pereipod.

B. Ventral view of the same. Note the absence of the genital opening on the third pereipod and the absence of the hook on the ischiopodite of the same appendage. A, Annulus ventralis; B, Male genital opening on coxopodite of the fifth pereipod; C-D, First and second pleopods showing structures characteristic of the male.

A specimen of *Cambarus rusticus* is described as follows: "[1]The specimen is externally a female, possessing the female type of claws, a well developed annulus, female sexual openings, and no hooks on the third pereipods. But the first pleopods are peculiar; they are short and stout; the bases are identical with those of the male pleopods; the distal parts, however, reach only to about the middle of the coxopodites of the fourth pereipods; their tips are soft, blunt and slightly curved inward, and possess the furrow which divides them into an inner and an outer part, but these parts are not separated at the tips. The second pleopods are of the female type. The specimen is apparently a normal female only the first pleopods are transformed in a peculiar way, resembling the male type generally, but differing from the specific shape."

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[1]Ortmann: The Crayfishes of the State of Pennsylvania.

LIFE HISTORY AND HABITS OF *POLISTES METRICUS*, SAY.

FRANK C. PELLETT.

The summer of 1915 was not a favorable season in which to study life histories of such insects as the Gold Banded Paper-Maker. The weather was too cool and there was so much rain that results were anything but satisfactory. It is very probable that in a season of normal temperature the time required in the various stages of development would be somewhat shorter than was the case in 1915. However, since I have spent considerable time in observing these insects during the past summer, I am hopeful that these notes may be of interest. Two years before, a similar observation was begun, only to be interrupted shortly by the destruction of the nest.

The nest of this wasp is composed of a single comb, or series of cells opening downward. Unlike the species of vespa commonly known as hornets and yellow jackets, no outer covering is provided. While the nests are often placed under the cornice of a house roof, they seem to be more often placed near the ground under a box, or in an old can or other similar situation. Discarded beehives and winter cases offer attractive situations on my grounds and I have found several of the nests during the past summer.

The first nest was found on June 6th. At that time about half of the cells were built and a count showed that eleven contained larvæ and fifteen contained eggs. Two or three partly finished cells were empty. This nest was placed underneath the cover of an empty beehive. A better situation for observation could hardly have been found, since it was possible to take up the cover and hold it in any desired position, and return it to the former place, without disturbing normal conditions.

Figure 43, A, shows the nest as it appeared at that time with the mother polistes resting above. To get the proper perspective the pictures should be held above the head and be seen from below instead of from above.

At first polistes was much disturbed by my presence and seemed very nervous and moved above restlessly when I was near. However, the nest was visited so frequently and so many hours spent in observing her movements that she soon manifested little interest in my movements. As soon as she

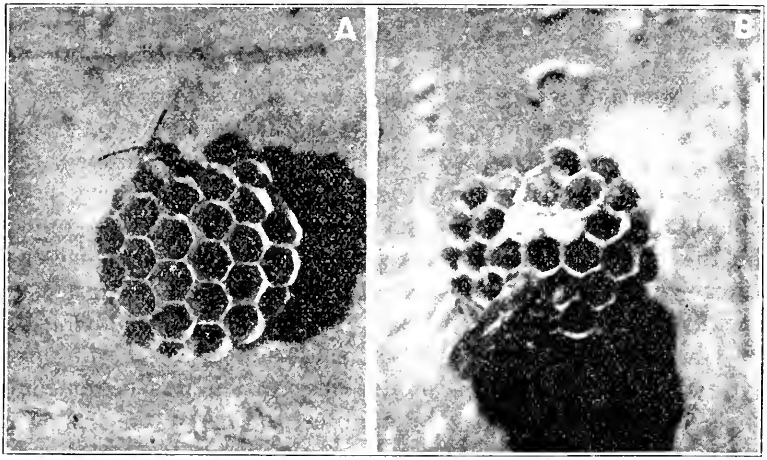

FIG. 43. A. Nest as it appeared when found. B. Polistes feeding her young.

became accustomed to my presence the cover was turned over, leaving the open end of the cells up to make observation easier. If the wasp flew away the cover always had to be replaced in its former position before she could find the nest again, although she would continue her normal activities with her house up-side-down.

The eggs were not placed in the center of the bottom of the cell where the queen bee deposits her eggs, but were attached to the sides of the cells a little above the bottom. When the eggs hatched they remained attached to the cell in the same position. The mother spent much time in feeding the young, giving them such attention very frequently on warm days, and also spent a great deal of time with her own toilet. After every feeding she would carefully clean first one leg and then another and brush every particle of dust off her body and head.

Soon after the nest was found the weather turned cool and it rained. With the temperature at about fifty degrees the mother settled herself quietly above the comb and made no move to feed her young or to continue her building. Even when visited and the nest turned topsy turvy, she hardly moved from her resting place. Although it remained cool for two days, the larvæ were not fed as far as could be seen. The weather warmed somewhat on the afternoon of the third day, but the wasp was not apparently conscious of it. The fourth day she became very active again, and fed the young almost constantly. At times she would bring little balls of food which apparently were caterpillars, which she had caught and kneaded into pulp between her mandibles. At other times she would seem to feed the very young larvæ when she apparently had nothing to give them. That she did feed them was evidenced by the movements of their lips after she withdrew from the cell. Apparently the very young larvæ are at times fed with regurgitated food. Usually the balls of food which she brought home were about the size of number eight shot. After kneading such a bit carefully, turning it round and round between her jaws, she would divide it into two or three parts and give it to the larger larvæ. Sometimes they would suck these bits for several minutes, when the mother would take them again and eat them herself or feed them to other larvæ. At other times, the youngsters would swallow them entirely after sucking them for some time.

One day I caught a mosquito, and rolling it between my finger and thumb, imitated as best I could, the kneading which the wasp gave the food. Then placing it on a grass stem it was given to a larva. The little larva opened its mouth much like a young bird waiting to be fed, took the mosquito and tried for some time to eat it. A red mite was caught and given to another larva in similar manner. The mite being very small was swallowed at once, but the other larva was still wrestling with the mosquito when the mother returned and took it away. After kneading it for a time, she ate it herself. Other mosquitoes were caught and offered in the same way, but she seized them, bit them viciously and dropped them at once. She became much agitated and flitted her wings in a most nervous manner. Such a bit was then fed to a larva without attracting the attention of the mother until it had tried for some time to dispose of it. Again she took it and kneaded it for a time and this time fed it to another larva, which swallowed it. Thus I took lessons in feeding the young larvæ, which were destined to stand me in good stead later in the season.

Some days elapsed before I saw the wasp in the act of enlarging her nest. I had seen her tear down parts of the cells when she was agitated and could hear the cutting of the paper with her sharp mandibles. After kneading the bits of paper for a moment, she had fed them to larvæ which ate them with apparent enjoyment. I had also seen her give a touch now and then as though in the act of adding something and had about decided that she did such work at odd moments, with but a touch here and there. However, on the 25th of June after nearly three weeks of watching, I saw her hard at work. It must be remembered that the weather was cool and wet and seldom favorable to activity of this kind.

She gathered her raw material near at hand and it was easy to follow her from her nest to a weather beaten post a few feet distant, where she secured her wood. After alighting on the post she would cut away enough of the exposed wood to make a good mouthful. She would then fly directly to the nest where she would stand for a moment kneading the pulp between her jaws and with her forefeet turning it round and round. She would then spend some time looking over the comb to find the most favorable place to work. When she had satisfied herself as to the place to begin, she would bite the soft pulp against the top of the partly constructed cell. It seemed very soft and waxy and spread easily. She pushed her forefeet against the opposite sides of the thin wall, backing slowly around the cell and drawing out the new tissue very thinly. Sometimes she would pass entirely around the cell and sometimes only part way. At times she would add as much as a sixteenth of an inch to the structure with a single mouthful and but two or three minutes were necessary to get fresh load of raw material. After each trip she would rest for a moment and make her toilet. Then she would peek into a few cells and be off again for another load.

Between times, she made a very elaborate toilet, sometimes standing on her hind legs and rubbing the other four together. At other times she would stand on her forelegs and extend the others behind her. Rarely she stood on her right middle leg in about her normal condition and stroked herself with the others as well as rubbing them together. Standing thus on one leg she presented a striking appearance.

Although much time was spent with the wasps nearly every day, it was a long time before the mother was observed in the act of laying. When the weather was nice she laid an egg nearly every day, as was observed by careful note of all empty cells. In cool weather she would sometimes miss a day, or even two or three. She laid on the 11th and 12th of June, then again on the 14th and 15th. Only one more egg was laid until the 20th. Apparently the wasp was very sensitive to weather conditions.

Finally by noting the conditions at the various times of my visits it was determined that the eggs were laid in the morning between eight and eleven o'clock. Accordingly on the last day of June, even though I had an engagement in a distant city, I determined to see the egg laid before leaving. I took up my watch shortly after eight o'clock and waited rather impatiently. The mother was rather sluggish and there was little action to keep up interest for nearly two hours, before she began preparing for her day's work. She would remain entirely motionless for many minutes at a time, then she would look into a few cells, and again become quiet. Finally about ten-thirty a. m., she flew away and was gone but a few minutes. On her return she began looking about in search of an empty cell. Finding one by pushing her head deeply into it, she doubled herself very shortly, and reversed her position, placing her abdomen into the same cell. She then remained very quiet with her head toward the center of the comb for several minutes. At last she moved out and again put her head in to see that the newly laid egg was in its proper place. Afterward she again became quiet for some time. Although I came near missing the train as a result of the long wait, I felt that the time had been well spent, and thereafter had no further difficulty in observing the egg laying as frequently as I wished.

A number of eggs were marked to ascertain the period required for hatching. Most of them hatched in just eighteen days. When the weather warmed a bit some hatched in sixteen days. Since the weather was cool and the temperature so much below normal probably this is longer than the normal period. A number of those observed spinning their cocoons spent twenty-three days in the pupal state. A few individuals required twenty-five days to complete the transformation.

Two years before, some under observation completed this stage in only fifteen days according to my notes, which indicates that weather greatly influences the length of the various periods of development.

When the larvæ had completed their growth, the spinning of the cocoons was an interesting observation. It was on the 24th of June that the first two completed this performance. Although the operation was not timed, probably not more than an hour was required to spin the cocoon. The silk was very filmy and so fine that a single strand could hardly be seen with the naked eye. During the spinning the larvæ moved their heads back and forth, round and round, constantly adding to the web. At first it was very thin and the inmate of the cell could plainly be seen at work through the thin network. It gradually thickened, until the spinner was entirely hidden from view, although the movement continued for some time after the covering became opaque.

Thinking to see something of the transformation a small hole was cut in the top of one of the cocoons. The day following the cell was found to have been emptied and a new egg placed therein. Apparently this change is not for the eyes of man to see.

As the days passed, the experiment of feeding the larvæ was continued. Mosquitoes being plentiful in the weeds near at hand, they were caught daily and fed to the larvæ. At times the mother would take them away and eat them herself. At other times she would feed them to the youngsters as already described. More often she would resent the interference with her family affairs and toss the dead mosquito contemptuously away. At times when she became nervous or angry she would cut the tops of some of her paper cells. Snip, snip she would cut away using her mandibles like a pair of scissors. Although on such occasions she was watched closely, she was not again seen to feed the paper to her offspring as in the one instance already described. When she was offered small caterpillars in place of the mosquitoes, she would accept them readily, roll them up into a ball and knead it vigorously and then feed the larvæ.

On warm days polistes was very active. Between her building and the feeding of the larvæ she was busy, indeed. After each trip afield, whether for food or wood pulp, she would tarry for a minute or two to clean herself carefully from any clinging dust and be off again. As the season advanced the number of larvæ increased and made a corresponding demand upon their mother for food. By the middle of July several had spun their cocoons, but more eggs were being laid in the newly built cells and other eggs were hatching.

On the morning of the 16th of July the nest was visited as usual. There had been a heavy rain lasting through most of the night before. The nest was dislodged and had fallen to the ground and the mother wasp was nowhere to be seen. The nest was carefully replaced and fastened to the board with glue and pins. After waiting all day for the return of the mother it became apparent that she was lost. I could ill afford to lose the wasp family at this stage of the observation, for eggs, larvæ and pupae were marked to ascertain the period of development. Near at hand was another similar nest, but the mother was not a lively individual, and the nest was composed of but a few cells. The nest containing the motherless family was fastened close beside her own to ascertain whether she would adopt the unfortunates.

The foster mother did not take kindly to such an arrangement and moved rapidly over the strange comb, flitting her wings violently, and showing marked evidence of displeasure. Since she had seldom been visited I felt that possibly my presence was responsible for her agitation, and accordingly she was left alone until the following morning in order to give her an opportunity to become accustomed to the unusual condition. On my return the next day she had her head in a cell and backed out with an egg in her mandibles which she proceeded to eat. An examination showed that she had disposed of some of the larvæ in similar manner. Since I could ill afford to have the observation terminated in such a cannibalistic manner, the nest was taken to the study to see what could be done toward raising the youngsters by hand.

I soon realized that I had undertaken a rather novel experiment. There were eggs which would hatch every day or two for three weeks, young larvæ just hatched and others in every stage of growth. There were also a considerable number of sealed cells, but as yet none of the pupæ had emerged. I began to frequent the cabbage patch in search of small caterpillars or cut worms. The unfortunate worm when found would be placed on a board and cut into bits with a sharp knife. The bits were fed to the larvæ with a grass stem. It was found easily possible to feed the larvæ, but the younger ones did not thrive.

On the 18th of July the first wasp emerged. It was a female and a perfect image of her missing mother. I now felt my hopes rise high, for would not the newly matured polistes mother her unfortunate sisters. The nest was placed on the porch of the study in order to give her an opportunity to fly to the fields in search of food, as soon as she was old

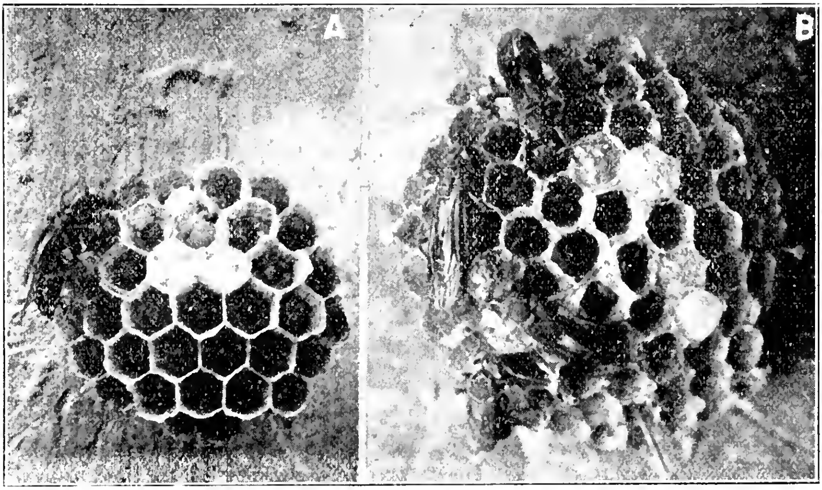

FIG 44. A. Larva spinning its cocoon. B. The completed nest.

enough to assume such a responsibility. The same day a second female emerged, and I felt that soon I would be relieved of my arduous task. It is not easy for a mere man to mother his own offspring at a tender age, and when it comes to feeding newly hatched wasps, he is hardly prepared to do justice to the needs of the infants.

Within a few hours after the emergence of the young wasps, a caterpillar was cut up for the young larvæ as usual. Instead of feeding it to them directly, it was given to one of the elder sisters to whom I was looking for expert assistance. To my great joy she took it and holding it between her forelegs, kneaded it exactly as I had seen her mother do many times. After the food had received suitable preparation she fed one or two of the larvæ. This action within a few hours after her own emergence convinced me that my troubles were over. However, I was doomed to disappointment, for this proved an unusual case. As others matured and the nest became populous with adult females I was greatly disappointed to find that they not only would not forage for the family but only now and then would they take the trouble to feed the infants when worms were brought to them. The mature wasps remained but a few days until they disappeared.

By the fifth of August about a dozen had emerged and only one remained at the nest. A larva which had hatched on the 29th of June died that day. Although I had kept it alive for twenty days after its mother disappeared it was apparently no larger than when she herself had last fed it. While my careful ministration had been sufficient to enable the larger larvæ to complete their growth the food which I was able to supply did not meet the needs of the younger ones. Either it was not suitable in quality, was not properly prepared or else it was not supplied in sufficient quantity or at proper times. At any rate I did not succeed in rearing any of the larvæ that were less than half grown when the mother disappeared.

About this time I found another nest of the same kind under the eaves of the study and having given up hope of further success by hand, the nest containing the motherless family was pinned beside it to see whether there would be any better success in getting the orphans adopted than in the previous instance. The weather was still cool and wet. The summer of 1915 was a record breaker in this respect. A week later the abandoned nest still remained beside the other, but the mother of that family had apparently gone also. Two other nests were examined at that time only to find them deserted.

On the same day, August 12th, I found another nest of polistes which previously had been overlooked. It was larger and more populous than any of the others. All the others except the unfortunate one which had received so much attention had been small and all the mothers had disappeared early. Since no males had been seen up to this time I was much pleased to find a family in normal condition. An examination showed that there were still eggs and young larvæ in the new nest, beside pupæ and seven adult females. I was so curious about the new discovery that four stings were the net result of the first day's observation. On September 4, there was only one egg still unhatched but no males had appeared. It was not until September 10, that the first male emerged. He was recognized instantly by his lighter color and bright yellow face. The seven segments of the abdomen and the absence of a sting established the sex beyond question. For several days about as many males emerged as females, but soon the males predominated. By the 21st of September more males remained at the nest than females. Since as many wasps were deserting the nest as were emerging from the pupal state, there was no permanent increase in the population.

The last larva died on October 3d. It was nearly grown but apparently had not increased in size for many days. Apparently it was fed just enough to keep it alive but not enough to enable it to complete its development. It was about the size of one that was hatched on August 10th. Although the date of the hatching of this particular larva had not been noted, indications were that it was about the same age. If so it lived for about fifty days without being able to complete its development. At that time there were a few sealed cells from which pupae were still to emerge and one lone female remained at the nest. The season had been so abnormal that it was impossible to make satisfactory observations on which to base an estimate of the normal period required to complete the life cycle. It so happened that something happened to every larva marked to ascertain the time of the larval period and it was evident that the variation was so great on account of variable weather conditions that the period required by a single one would have been of little value. While I am hopeful of getting more satisfactory information concerning the periods of development another season I have no expectation of again attempting to rear a family of wasps by hand.

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SUCCESSFUL "MINK FARMING" IN IOWA.

B. H. BAILEY.

Through the kindness of Prof. C. C. Nutting, Senator Lambert and his brother, Mr. C. Lambert, of Sabula, Iowa, the writer was afforded an opportunity to visit and study the "mink farm" owned by Mr. C. Lambert and J. E. Densmore, of Sabula, Iowa.

The mink has been regarded as one of the most difficult animals to rear in captivity, owing to its natural temper and habits, but the present successful effort which was started in 1910 has added not a little to our knowledge of the mink in captivity and the best methods of handling it.

There are at present in this "minkery" thirty-seven individuals. These are all in perfect health and under absolute control of the owners. The individual cages in which they are kept insure the isolation which is natural to the animals in their native state, and at the same time afford an opportunity for close observation of each individual as well as a perfect control of each in feeding and breeding.

The first litter of six young was born in captivity May 7, 1910. They were the offspring of a female which was secured by trapping. Only three out of the thirty-seven which now occupy the cages were trapped. The rest have all been born in captivity. The advantage of having minks raised in captivity for breeding purposes rather than those that have been trapped, lies in the fact that they are more docile, and having known no other home do not seek to escape. An excellent illustration of this fact came under the observation of the owners at one time. A board having been loosened in one of the cages, there was given an opportunity to one of the animals to make its way out. The mink availed itself of this opportunity but was not missed until it was seen coming home. It entered the cage by the same opening through which it had made its exit, and gave every evidence of having come back because it regarded this place as its natural abode. On another occasion a mink was reported at some distance from the mink farm. The animal had entered a chicken-house and had killed two chickens when it was discovered by the woman who owned the fowls. She drove the mink out of the chicken-house, but it ran in again, keeping just out of her reach. She reported the occurrence to Mr. Lambert because the mink appeared to be so tame and apparently feared her so little. This animal later returned to the cage. Mr. Lambert was not aware that there had been any successful efforts to rear minks in captivity elsewhere in the state of Iowa at the time of his first experiments. His purpose originally was to demonstrate in the first place that it is possible to rear these animals in captivity and in the second place the advance in the price of furs would, he thought, warrant the raising of these animals for their pelts, provided they could be ored successfully and their fur kept in as good condition as in the wild state. He is satisfied as to both these points and believes that there need only be a suitable market to make the business a profitable one.

Some years ago Mr. Lambert sold as beautiful pelts as he had ever seen for seventy-five cents each. In 1911, No. 1 extra large dark minks were bringing $9.00. The price in 1916 has ranged between five and six dollars.

Among the interesting facts which have been noted with regard to these captive minks are the following:

The usual breeding season in this locality is from the 10th or 12th of March to about the end of the first week in April.

The period of gestation is six weeks and the litters range from three to seven. The average litter is four or five, and but one litter is raised in a year. The young are about an inch and a half to two inches long at birth and it is a number of days before they open their eyes.

Young male minks can usually be recognized by their size, as they are slightly larger than the females.

The cry of the little ones is a high pitched whine. In the wild state, the mink is known to move its young from one locality to another if it is in the least disturbed. This tendency is noticeable in the animals in confinement. The only period when the mink is not a solitary animal seems to be during the time when the female is caring for the young. By the following spring the young animals have attained their adult size and do not seem to grow after they are two years old. They may lay on flesh, becoming heavier, but the bony framework does not seem to enlarge. Male minks born during one year will breed the following spring.

Since the animals do not pair, but in their natural haunts are accustomed to travel about, the males going long distances from place to place during the breeding season, it has been noted with interest that one male will serve several females, and it is the custom usually to use the male not oftener than every other day.

The cry of the male is a short grunting snuffle. The female gives a high pitched squealing cry. The offensive odor of the scent glands, noticed when the hide is being removed from a dead mink, was not noticeable about the pens, except at the time when a pair were being bred.

It is known that in its natural haunts the mink will accommodate itself to almost any hole that is dry. In the cages small boxes about eight inches square and a foot and a half long, having a circular opening about four inches in diameter at one end, and partly filled with grass, afford a suitable substitute for their natural homes. It is known that minks will sometimes climb into trees if closely pursued by dogs, and their ability to run about on various surfaces was noticed in the cages, where they were exceedingly agile and very noisy. They seemed to enjoy pushing their water pans about, apparently for the purpose of hearing the clatter, and when one approached the front of the cage, the animals in many instances climbed up on the quarter inch wire mesh, showing almost the agility of squirrels.

The food supplied to these captive minks is doubtless much the same as is procured by the wild animals. They enjoy fish, crayfish, musk rats, and rabbits above other foods, and also eat mice, wild birds, poultry and beef steak. A mixture of corn meal mush with a little tallow, has been successfully fed to minks in captivity, and they also will eat bread and milk. It is found that salted food if continuously fed is fatal. On one occasion when some salted fish were fed, fourteen or fifteen young died as a result of eating them. The full grown mink will readily go into the water and capture a fish twelve inches long or more, and eventually devour the bones and all. It is a habit where there are several fish in a small pool to kill all before eating any of them. A live rabbit which was introduced into one of the cages was very quickly killed by a male mink.

It is the custom to feed minks in captivity once a day. Running water is preferable, but not necessary, and it was noted that where water has been frozen in the pans the minks gnawed at the ice and lapped up the particles that were dislodged. The method of drinking milk is similar to that of the cat.

The mink is a very cleanly animal, and the cages which, because of the cold weather, had not been cleaned recently, were wholesome and free from odor.

The chief factor in the success of this mink farm lies in the care and skill shown by the owners in housing, feeding, and breeding.

The individual cages are about six feet long by three feet high, and three feet wide. They are built of pine and wire mesh, the pine box having part of the top at one end and all of the contiguous end of one-fourth inch mesh wire. That part of the top which is of wire swings upward on hinges and affords easy access to the interior of the cage. Within, on the floor, is a litter of straw and grass, a pan for water, and the box previously described, in which the mink makes its nest.

It has been found best not to handle them and the easy method by which handling is avoided and the supposedly difficult process of getting an animal from one cage to another simplified, reveals the careful planning by the owners in the conduct of this experiment. Along the front of each cage and connecting each cage to every other one in the house is a small wire-constructed alley about six inches high and wide. At each partition between cages, this alley is fitted with a sliding drop door, much like the stop to a grain spout. The door from the cage into the alley way is similarly guarded by a drop door which can readily be operated from the outside of the cage. If it is desired to clean the cage this door is raised, a little rattling of the wire induces the mink to enter the run-way, the door is closed and he is prevented from going back into the cage, and can not follow the run-way farther than to the limits of the partitions between the cages, where, as noted before, there are drop doors to close that particular section. The run-way so closed forms a box three feet long by six inches wide and high.

If it is desired to transfer this animal to any other cage, the alley-way is opened all the way to the cage which it is desired to have the mink enter, and the door is opened into that cage.

No other mink can enter the runway at that time and the animal in the run-way can go only to the place intended.

The advantage of this method of control is evident in breeding, since exact records are kept of the date of breeding, and the pedigree of the animals bred.

The docility of the animals, their evident lack of shyness and the readiness with which they are induced to go in the direction desired evidences the careful work of the owners.

The houses, or rather sheds, used at Sabula are cement floored and built much like chickenhouses. There are sky-lights but Mr. Lambert believes that the more the animals are kept in the dark the better will be their fur.

In one of the two houses there were twenty-six cages, and twenty-four in the other. A device for running water is being installed that will doubtless be a convenience to the owners and a comfort and pleasure to the minks.

Up to the present time at the minkery, no animals have been killed for the fur since it is desired to increase the stock for supplying other "minkeries."

The readiness with which such an industry might be developed, since the entire equipment requires only a part of an ordinary city lot, and the fact that since in most towns running water is as accessible as in the country, makes it a suitable industry for the city as well as the country.

A "minkery" in your back yard or in your neighbor's, would conduce to more neighborly feelings and sounder sleep of mornings than a hen yard, especially if a couple of lusty roosters are included among the inmates.

Former experiments in mink raising have failed on account of ignorance of the real needs of these animals and of their habits. They can not be allowed to run together as the males fight fiercely and inbreeding would weaken the stock. The care afforded each individual mink from the time its parents are selected to the time it reaches maturity, results in producing large animals with fur that is of a superior quality and that need be taken only when the fur is prime.

It is a beautiful sight to see these little sleek-bodied active animals moving about the cage and coming to the wire unafraid when one approaches the cages, and the contrast is more marked to one who knows the sly, secretive, vicious character of these animals in the wild. When the old time trapper shall have passed and the last pair of steel jaws shall have rusted away, we may still wrap ourselves comfortably from the wintry blasts because of the successful solution of those who have established the industry of mink farming.

ADDITIONAL NOTES ON THE LITTLE SPOTTED SKUNK, *SPILOGALE INTERRUPTA* RAF.

B. H. BAILEY.

In volume XXII of the Proceedings of the Iowa Academy of Science, it was shown that the Little Spotted Skunk is statewide in its distribution. Since writing the last article, I have received specimens from Muscatine, Iowa, from Mr. J. Greenblatt; also from Mr. Christian Hoeg, of Decorah, Iowa, who states that they seem to be quite common in that vicinity; and also from Sabula, Iowa, at which place Mr. J. C. Day and son had received during the winter of 1915 and 1916, up to the 17th of March, 1916, twenty-five pelts of "civet cats," trapped in the immediate vicinity of Sabula. Further effort to discover whether the Little Spotted Skunk has crossed the Mississippi to the Illinois side has resulted negatively in the region of Muscatine and Davenport, but from Mr. C. H. Swift of Sabula, Iowa, I learned that he had personally trapped two specimens of the Little Spotted Skunk on the Illinois side of the Mississippi river, north of Savannah, "twenty years ago." These two specimens were caught while trapping for larger skunks. That they have not become common in that region is evident by the testimony of several men in Savannah, notably, Mr. George N. Machen, who has for many years been a close observer of the wild life in that region. Careful inquiry has further confirmed the statement that "civet cats" are far less abundant in the eastern part of the state than are the common large skunks, and that they become relatively more numerous in middle and western Iowa. The firm of J. C. Day & Son, at Sabula, up to date, had purchased 814 hides of the common skunk, while as before stated, only twenty-five skins of the "civit cat" or Little Spotted Skunk had been purchased during the same time.

DEPARTMENT OF ZOOLOGY,
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NOTES ON TWO STRAWBERRY SLUGS. *EMPRIA FRAGARIÆ* ROHWER. *EMPRIA MACULATA* NORTON.

R. L. WEBSTER.

The literature of economic entomology has many references to slugs that feed on strawberry foliage, discussed for the most part under the name of *Harpiphorus maculatus* Norton, but also as *Monostegia ignota* Norton. That there were two common species of these slugs affecting strawberry plants was shown by the work of F. W. Mally (1889). During the five years 1910-1914 inclusive, the writer has studied both these species in the insectary at Ames. The present paper is based on a study of the literature, as well as from additional notes of the writer. S. A. Rohwer, of the U. S. National Museum at Washington, examined all the saw-flies reared, and has recently described *Empria fragariae*. The life history notes are from the files of the entomological section of the Iowa Agricultural Experiment station at Ames. These insects are discussed in a recent bulletin from the Iowa station but some matter is incorporated here that is not mentioned in the bulletin.

Dr. C. V. Riley (1867), first mentioned *Emphytus maculatus* in the economic literature in the Prairie Farmer. This was followed by an account by Walsh and Riley (1869) and later by Riley (1877). These refer to slugs feeding on strawberry foliage in May (Missouri). The eggs are said to be deposited in the stems of the strawberry leaves and a second brood of slugs are said to appear in July. The slugs are described as having a yellowish head, with two dark brown spots above, one of these to the front, as well as two smaller ones at each side.

Dr. Riley (1868) said that slugs had injured strawberry plants at Rockford, Illinois, and Cedar Bluffs, Iowa. He remarked that these slugs were probably a variety of *Emphytus maculatus*, since they had but one black spot on each side of the head. This corresponds to the description of *Empria fragariae*, later discussed by F. W. Mally under the name of *Monostegia ignota*.

Forbes (1884) gave a general account of *Emphytus maculatus*, adapted from previous accounts by Riley and others. Here doubt is expressed concerning a second generation, since, aside from Riley, none had been seen by other observers.

In the same year Forbes (Ill. Hort. Soc. Rep.) treated briefly a strawberry slug under the name of *Emphytus maculatus.* In breeding this insect only one generation was found. The eggs were deposited beneath the epidermis of the leaf. Probably the insect concerned was *Empria fragariae*, which places its eggs in the leaf tissue.

F. M. Webster (1888), recorded the abundance of larvæ supposed to be *Emphytus maculatus* at Richmond, Indiana, in October, 1887. This appeared to indicate a second generation.

F. W. Mally (1889) was the first to point out clearly the presence of a second species of strawberry slug, differing in several respects from that discussed by Riley. Specimens sent by Mally to E. T. Cresson were determined as probably *Monostegia ignota* Norton. That the species reared by Mally is really *Empria fragariae* will be shown later on.

The main points established by Mally's work are these: (1) that two species of slugs are found on strawberry foliage in Iowa, (2) that these are easily distinguished in the larval stage and (3) that the eggs of the second species (*Empria fragariae*) are placed in the leaves, not in the stems. Later (1890) Mally showed that only one generation of this insect occurred in central Iowa.

F. M. Webster (1894) secured larvæ from strawberry plants at La Porte, Indiana, July 5, 1893. These entered the soil in an insectary cage, remained there all winter, and adults emerged the next March. Adults deposited eggs in stems of strawberry plants and specimens were determined by Dr. L. O. Howard, as *Harpiphorus maculatus.*

Dyar (1896). described seven larval stages of *Harpiphorus maculatus* and recorded rearing adults of that species from larvæ with immaculate heads, apparently contradicting Mally's observations. From these descriptions, however, it seems probable that Dyar had only the one species, *maculata*, and may not have seen specimens of the insect considered by Mally as *Monostegia ignota.*

In Michigan R. H. Pettit (1899) recorded larvæ that he called *Harpiphorus maculatus* occurring at Stevensville and elsewhere in the state in the late summer of 1898. Larvæ about mature were reported for September 22.

J. M. Stedman (1901) gave a general account, under the name of *Harpiphorus maculatus*, of a strawberry slug occurring in Missouri. An examination of this bulletin, however, shows that it was not that species which Stedman studied. The life history and habits agree precisely with those of *Empria fragariae*, as described by F. W. Mally and as determined more recently by the writer. The deposition of eggs in the leaves and the appearance of adults and larvæ in early spring (about strawberry blossom time) shows that Stedman was writing of this insect under the wrong name. I have attempted to obtain reared specimens of the saw-fly from Columbia, but Dr. L. Haseman writes that he finds none in the collection there.

S. A. Rohwer (1914) described *Empria fragariae* from specimens reared or collected by the writer in Iowa. That this is the same insect discussed by F. W. Mally is shown by the facts (1) that most of the material was collected in the same locality, about Ames, (2) that the life history is the same: the saw-flies appear early in spring (before strawberry blossom time) and the eggs are placed in the leaves. Moreover, the writer found only one generation, as did Mally with his *Monostegia ignota*. Unfortunately, there are no specimens reared by Mally in the collection at Iowa State College, so that an actual comparison of specimens is not possible.

GENERATIONS OF EMPRIA FRAGARIAE.

From the literature it is very apparent that *Empria fragariae* has only one generation. The work of Forbes (1884) which apparently refers to this insect, of Mally (1890), and of Stedman (1901), all show this. Life history experiments by the writer more recently show but one generation in central Iowa. The insect has been carried through to the adult stage each year during four years, and in no case was there any evidence of a second generation.

Briefly, the life history of *Empria fragariae* is as follows: The adults emerge very early in spring, in April in central Iowa, deposit their eggs singly in strawberry leaves, and larvæ appear at the blossoming time of the strawberry. The slugs mature in about a month, enter the soil, where they remain until the next spring, pupating shortly before the adults emerge.

GENERATIONS OF EMPRIA MACULATA.

Here the situation is more complicated. In the literature we have the definite statement by Riley that the insect has two generations in Missouri, and the statements of F. M. Webster (1888) and Pettit (1899) that larvæ were found in abundance in the fall in Indiana and Michigan. On the other hand, no other writers have been able to discover a definite second generation. In fact, F. M. Webster (1894) determined a single generation from larvæ collected at La Porte, in northern Indiana.

The writer has bred this saw-fly in the insectary at Ames during four years, and each year there was but a single generation. According to these notes the life history in central Iowa is as follows: The adults emerge in late April or early May and deposit their eggs in the stems of strawberry plants. The larvæ hatch in late May and are present during June, mature and enter the soil about a month after hatching. Larvæ spend the winter in the cocoons, pupating the next spring shortly before the adults emerge. Adults reared in the insectary have been identified by S. A. Rohwer as *Empria maculata* Norton.

Eliminating references in the literature that clearly refer to *Empria fragariae*, the following generalizations are offered:

(1) Riley claimed two generations for Missouri. This may be possible, since it has not been proved otherwise.

(2) F. M. Webster determined only one generation from larvæ from La Porte in northern Indiana, in 1894.

(3) Only one generation is present in central Iowa, according to notes by the writer.

(4) This does not dispose of the statements that this insect has been seen in the fall in southern Indiana (Webster) and Michigan (Pettit).

(5) There still remains a possibility that there is a third species of saw-fly, the larvæ of which attack strawberry plants in the fall, but which has not been recognized in the economic literature as a separate species.*

*Emphytus gillettei MacG. feeds on strawberry foliage in Colorado but there is only one generation. The eggs are placed in the leaf tissue and larvae appear in late May and early June.

The following table shows certain characteristics that distinguish these two species of strawberry slugs. The time of the season applies to central Iowa.

	Empria fragariae	*Empria maculata.*
Generations	One	One
Adults appear	Early April	Late April
Eggs deposited	In leaves	In stems
Larvæ appear	May (blossoms)	June (as fruit ripens)
Larvæ begin feeding	On upper epidermis	On lower epidermis
Head width stage I	.51 mm.	.32 mm.
Head markings	None	Dark markings above and at sides

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BIBLIOGRAPHY.

1861. *Norton, Edward,* Proc. Bost. Soc. Nat. Hist., vol. 8, p. 157. *Emphytus maculatus* described.

1868. *Riley, C. V.,* Trans. Ill. State Hort. Soc. for 1867, p. 121. Mentions slugs injuring strawberry plants at Rockford, Illinois, and Cedar Bluffs, Iowa. Says that these were probably a variety of *Emphytus maculatus,* the larvæ having but one black eye spot on each side.

1869. *Walsh, B. D., and Riley, C. V.,* Amer. Entom., vol. 1, p. 90. General account. Mentions two generations (*Emphytus maculatus*).

1877. *Riley, C. V.,* Ninth Mo. Rep., p. 27. General account. *Emphytus maculatus.*

1884. *Forbes, S. A.,* Trans. Ill. St. Hort. Soc. for 1883, p. 121. Mentions *Emphytus maculatus* and says that only one generation was found. Also found eggs beneath the epidermis on the under side of the leaves.

Forbes, S. A.. Thirteenth Ill. Rep., p. 71. General account. *Emphytus maculatus.*

1888. *Webster, F. M.,* Rep. Comm. Agr., 1887, p. 152. Larvæ supposed to be this species (*Emphytus maculatus*) observed in October near Richmond, Indiana.

1889. *Mally, F. W.*, Insect Life, vol. 2, p. 138. Gives an excellent account of the life history and habits of *Empria fragariae*, with distinguishing characters separating it from *Empria maculata (Monostegia ignota).*

1890. *Mally, F. W.*, Insect Life, vol. 3, p. 9. Describes the male of *Empria fragariae* and gives additional notes. (*Monostegia ignota.*)

1894. *Webster, F. M.*, Entom. News, vol. 5, p. 275. Number of generations of *Empria maculata.* (*Harpiphorus maculatus.*)

1896. *Webster, F. M.*, Bull. Ohio Agr. Exp. Sta., 68, p. 33. General account. Only one generation proven. (*Harpiphorus maculatus.*)

Dyar, H. G., Can. Ent., vol. 28, p. 236. Descriptions of the larval stages of *Empria maculata.* Says that this is identical with *Monostegia ignota.*

1899. *Pettit, R. H.*, Bull. Mich. Agr. Exp. Sta., 175, p. 365. Larvæ said to have been observed in September, 1898, in Michigan. (*Harpiphorus maculatus.*)

1901. *Stedman, J. M.*, Bull. Mo. Agr. Exp. Sta. 54. General account. The insect treated is called *Harpiphorus maculatus*, but the account of the life history and habits is clearly that of *Empria fragariae.*

1914. *Rohwer, S. A.*, Journ. Econ. Ent., vol. 7, p. 479. *Empria fragariae* described.

1915. *Webster, R. L.*, Bull. Iowa Agr. Exp. Sta., 162. General accounts of *Empria fragariae* and *Empria maculata.*

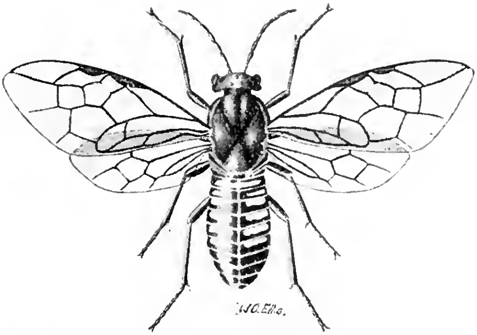

FIG. 1.

FIG. 2.

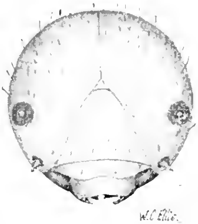

FIG. 3.

FIG. 4.

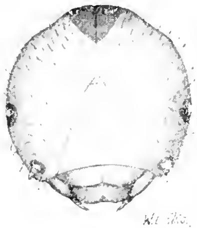

FIG. 5.

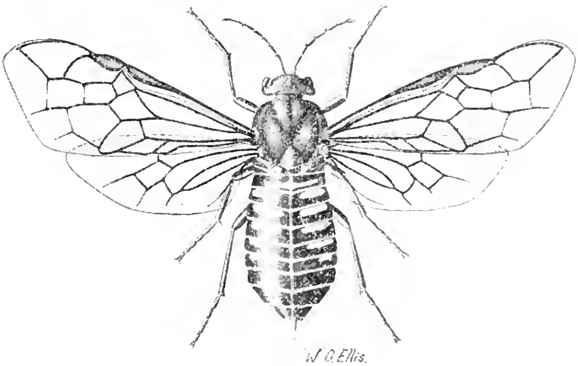

FIG. 6.

FIG. 1—The adult saw-fly. *Empria maculata.* Enlarged 5 times.
FIG. 2—*Empria fragariae.* Eggs on a strawberry leaf. Enlarged.
FIG. 3—*Empria fragariae.* Head of mature larva. Enlarged.
FIG. 4—*Empria maculata.* Head of larva from side. Enlarged.
FIG. 5—*Empria maculata.* Head of larva from front. Enlarged.
FIG. 6—*Empria fragariae.* The adult saw-fly. Enlarged 5 times.

A METHOD OF PREPARING STUDIES OF *TRICHINELLA SPIRALIS* OWEN.

T. T. JOB AND DAYTON STONER.

This work was first attempted with the idea in mind of securing an adequate supply of laboratory material of *Trichinella spiralis* for classes in invertebrate Zoology at the State University of Iowa.

It is the too general belief that such studies are difficult to secure and it is to dispel this idea, in part, that this paper is offered. In fact the comparative ease with which one may secure a presentable series showing the development, growth, migration, encystment, etc., of this worm, affords an unusually good opportunity for illustrating the interesting phenomenon of typical parasitic life.

Since it is often rather difficult to secure trichinized meat from the local shops, the material for the following studies was obtained by addressing the Chief of the United States Bureau of Animal Industry at Washington, D. C. This meat contained the worms in the encysted stage and in suitable condition for transferring to another host where they might live and reproduce.

A part of the trichinized pork was fed to four young white rats which were kept confined in a separate cage. After having eaten of this pork the rats were again given their usual diet.

THE TRICHINELLAE AND HOST.

Host No. 1.—Five days after feeding the encysted Trichinellæ the first subject was killed. Various openings were made at different levels in the stomach and intestine and the digestive content together with scrapings from the mucosa were examined under the dissecting microscope in 5 per cent formalin.

Free worms were found only in the intestinal content and the mucosa of the upper ileum. Sections of this portion of the intestine were preserved in 10 per cent formalin.

Host No. 2.—Nine days after feeding, a second subject was killed. The procedure was as in No. 1. In addition, an examination of several blood smears from the superior mesenteric vein and the heart was made. Only one young Trichinella was found in the smears and that in the blood from the heart. The embryos at this stage were developed to such an extent that they could readily be seen in the body cavity of the female.

Again sections of the upper ileum were preserved in 10 per cent formalin.

Host No. 3.—Fourteen days after feeding, the third subject was killed. The method was as above. Blood smears were negative. The Trichinellæ were found a little further down in the ileum and were much larger than in the nine day stage.

Host No. 4.—The fourth subject was to have been killed twenty-one days after feeding, but it died of trichinosus on the night of the twentieth day.

On examination, free intestinal Trichinellæ were found in the middle ileum. The muscles surrounding the abdominal cavity, diaphragm, internal and external oblique, transversalis and psoas, as well as the extensor muscles of the hind legs showed Trichinellæ in the *migratory* and *resting* stages. A considerable number were found in these muscles but the masseter muscles showed the various stages even better and more abundantly.

In this stage the entire body of the host was preserved in 10 per cent formalin.

METHOD OF PREPARATION.

The material was handled in watch glasses with pipettes. First, the preserved material was washed thoroughly with distilled water. This not only removes the formalin but separates the Trichinellæ from the other material so that the worms may be collected in a pipette and transferred to the next dish. The staining and dehydration were carried on in the same dish so as not to injure or lose the specimens, the different fluids being added and drawn off with the pipette.

Killing and Fixing.—Ten per cent formalin was used in all cases to kill and fix the tissues and Trichinellæ. Carnoy's solution may be used with equally good results.

Staining.—Delafield's hematoxylin and erythrosin, orange G. methyl green, borax carmine and iron hematoxylin (Heidenhain) were all tried. Iron hematoxylin seemed to give the best results with borax carmine next. Where iron hematoxylin is used, care must be taken to remove all the surplus mordant or a precipitate will occur on addition of the hematoxylin thus vitiating the results. The borax carmine has the advantage in ease of handling.

Clearing—Experiments with xylol, oil of bergamot, chloroform and turpentine showed that all these clearing agents shriveled the specimens. As a matter of fact clearing is not at all necessary.

Mounting.—Specimens mounted in balsam were shriveled just as when treated with a clearing agent so glycerine was used as the mounting medium. The permanent mounts were ringed with lacquer or thick balsam.

It is, perhaps, needless to suggest that great caution be observed in regard to cleaning cages in which hosts are kept, means of disposition of their bodies and general cleanliness in handling specimens.

STATE UNIVERSITY OF IOWA.

DISTRIBUTIONAL NOTES ON SOME IOWA PENTATOMOIDEA.

DAYTON STONER.

During the past two summers the writer has been enabled, through the co-operation of the Iowa Geological Survey, to visit various parts of the state for purposes of collecting both mammals and insects. In the course of this collecting, some species of Pentatomoidea not before recorded from Iowa have been secured and, in addition, distributional records of a number of species have been added. Considerable collecting has been done in the vicinity of Iowa City also and this has resulted in some new additions to and increased the known distribution of the state fauna in this group.

As more intensive and extensive collecting is done it is interesting to note the considerable number of Pentatomids found in the state which are usually thought of as being of more southerly or westerly distribution. However, sufficient collecting has not yet been done to warrant any extended conclusions being drawn at this time. Since little work has been done by the writer in western Iowa, some six or seven species recorded by Professor Osborn more than a decade ago and mostly from that region remain to be found in the present study.

The species which follow do not represent the entire number found within the state but only those are included which would seem to be of especial interest at this stage of the work. With the conclusion of this paper sixty species of Pentatomoidea will have been recorded from Iowa through the efforts of Professor Herbert Osborn and the writer.

Family THYREOCORIDAE.

Subfamily Thyreocorinae.

Thyreocoris lateralis Fabr. Least common of the members of the subfamily.

Specimens at hand from Ames, Iowa City, McGregor, Anamosa and Solon.

Thyreocoris nitiduloides Wolff. Generally distributed over the state; apparently nowhere common.

Thyreocoris pulicaria Germar. This most common species of the family has been taken in almost every locality in which collecting has been done.

Thyreocoris unicolor P. B. First recorded from the state by the writer (Ent. News, XXVI, 1915, 354), and among the members of this family it ranks next in abundance to *T. pulicaria.* Specimens are at hand from Iowa City, Des Moines, Centerville, Hampton, Glenwood, Storm Lake, Fort Madison and several other intermediate points.

Subfamily CYDNINAE.

Cydnus obliquus Uhler. This species was first found in the state on May 22, 1915. It was discovered about the roots of Drop-seed Grass (*Sporobolus cryptandrus* (Torr.) Gray) on a sand area two miles north of Iowa City. This sand area is perhaps two acres in extent, is not cultivated and supports a vegetation characteristic of arid conditions. On the above-mentioned date five live specimens of this species were found. Nine days later another visit was made to the sand area and in a little over three hours twenty-seven specimens were secured. On this second visit also a pair of the bugs was found in copula. These Cydnids have not been found elsewhere in the state.

Geotomus parvulus Signoret. Two specimens of this species, each bearing an Ames locality label were recently discovered by the writer in the collection of the Iowa State College. This may possibly be the species to which Professor Osborn referred in the Proceedings of the Iowa Academy of Science, Volume V, page 232, 1897, where he lists "*Geotomus sp.*" from Iowa. No other Iowa records of this western form are at hand.

Schirus cinctus P. B. This species, first recorded from the state by the writer, (Ent. News, XXVI, 1915, 354), has been found in but two localities, Iowa City and Grinnell. At Iowa City it was taken from under dried grass along the edges of boards lying in a pasture in late March. March 25, 1916, it was taken from under leaves and some specimens were buried almost an inch below the surface of the earth beneath the leaves where they had been hibernating. The single Grinnell specimen was taken in July on wild raspberry.

Family SCUTELLERIDAE.

Subfamily Scutellerinae.

Homaemus aenifrons Say. Less common than the following. Three specimens from Ames, Hills and Iowa City.

Homaemus bijugis Uhler. Several specimens from Iowa City, Monticello, Waukon and Storm Lake. Professor Osborn recorded it also from Ames and Little Rock.

Eurygaster alternatus Say. Professor Osborn says of this species (Proc. Ia. Acad. Sci., Vol. I, part II, 1890-91) "not common," but no localities are cited. A single specimen has thus far been collected at Red Oak in July.

Family PENTATOMIDAE.

Subfamily Pentatominae.

Banasa dimidiata Say. Recorded from Ames by Professor Osborn who says further that it is "not common." One specimen, November 13, under fallen leaves.

Dendrocoris humeralis Uhler. Two localities only are represented, Solon and Robinson; August. The Robinson specimens were taken on hazel.

Euschistus ictericus Linn. Iowa City and Algona. Professor Osborn in Proceedings of the Iowa Academy of Science, Volume I, part II, 1890-91, records a single specimen of this species which he says was "doubtless taken in the state."

Euschistus tristigmus var. *pyrrhocerus* H-S. This variety of the typical *tristigmus* was not recorded by Osborn. All the specimens agree in having the humeri produced into long, acute spines and in having the antennae entirely pale; they also average somewhat smaller than *tristigmus*. Specimens from Iowa City and Solon only; taken in August and November. The August specimens were taken on wild raspberry and the November specimens from under dried leaves.

Euschistus variolarius P. B. Abundant. Collected in practically every locality. Apparently hibernates very successfully under leaves, sticks, grass, etc., and is often found in the same localities as *Hymenarcys aequalis* Say.

Menecles insertus Say. Osborn says of this species "rare." Our collection of twenty-four specimens does not contain material from other localities than Iowa City and in no case have they been secured by sweeping. Almost all the specimens have been found in autumn (November) under fallen leaves. mostly elm.

Mormidea lugens Fabr. Iowa City, Monticello, McGregor, Dubuque, Robinson, Solon, Hills. Nowhere common. Swept from blue grass in open fields in late June. Also found hibernating beneath leaves in March.

Murgantia histrionica Hahn. First recorded from Iowa by the writer (Ent. News, XXIV, 1913, 132). Since that time, although special search has been made, other specimens have not been found.

Neottiglossa sulcifrons Stål. This southern species was first (Ent. News, XXVI, 1915, 355) recorded from Chariton where a single adult specimen was found in July. Last summer this species was found in some numbers at Burlington, Fort Madison and Glenwood. It has also been found at Red Oak and Shenandoah, all in the southern part of the state. Nymphs of the species were taken at Burlington during the latter part of June and at Glenwood July 14. In all instances it has been swept from sparsely growing blue grass.

Peribalus limbolarius Stål. One of the commonest species of Pentatomid found in the state; perhaps next in abundance to *E. variolarius*.

Prionosoma podopioides Uhler. A western species that has been taken in June at Fort Madison near the extreme southeastern corner of the state. A single specimen has also been taken at Iowa City from under mullein leaves in October.

Solubea pugnax Fabr. Has been taken at Iowa City, Hills and Moscow. Swept from sparsely growing weeds on sandy soil.

Trichopepla atricornis Stål. Two specimens, both from Iowa City. Professor Osborn recorded it from Little Rock and Ames.

Trichopepla semivittata Say. Apparently not common anywhere. A few specimens from Boone, Red Oak and Fort Madison.

Brochymena arborea Say. Three specimens from Robinson. including a half-grown nymph; collected August 25 on wild crab apple. One other specimen from Iowa City.

Subfamily ASOPINAE.

Apateticus cynicus Say. Iowa City and Robinson. Professor Osborn says of this species "not abundant."

Podisus maculiventris Say. Quite common in almost every locality.

Podisus modestus Dallas. Professor Osborn records but a single specimen from Ames. A few specimens are at hand from Robinson.

Podisus placidus Uhler. Iowa City and Robinson.

Podisus sereiventris Uhler. Iowa City, Independence and Robinson.

STATE UNIVERSITY OF IOWA.

THE BEHAVIOR OF LEGUME BACTERIA IN ACID AND ALKALINE MEDIA.

RAYMOND C. SALTER.

Several investigators have noted a very marked difference in the resistance of various legumes to soil acidity. Vast areas of cultivated land in the United States show an acid reaction, and as lime is expensive in some localities it has been suggested that much can be saved by the choice of acid tolerant crops.[1] Red clover, crimson clover, soy bean, cowpea, hairy vetch, lupine and serradella have been reported as acid tolerant, while on the other hand, alfalfa, one of our most useful forage crops, is found to be very sensitive to acid.

This sensitiveness may be due to many factors concerning the nutrition of the plant. Since leguminous plants obtain nitrogen by a symbiotic relation with certain bacteria, it seems probable that the ill effects of the acid may be directly upon the symbiotic bacteria and only indirectly upon the higher plant.

The influence which the acid constituents of the soil may exert on plant growth has been studied chiefly with reference to the growth of higher plants. From the nature of the results of these investigations, it seemed advisable to extend the study to the lower plants. Probably one of the most striking examples of the interdependence of higher plants and bacteria, is the legumes and legume bacteria. Any agent affecting the one will have a corresponding effect on the other.

The growth of legume bacteria can be measured directly by plate counts, and their virulence can be tested by the formation of nodules on the host plant. This property of the organism makes it well suited for a study of the effect of acid and alkali on its development. An increase or decrease which might result will be noted, especially if the result is compared with that from a neutral culture.

Experiments were planned to study and compare the effect of acid and alkali on the bacteria and host plant. Since legumes are found to vary in resistance, the acid tolerant red clover

[1]Coville, F. V., Bul. 6, United States Dept. Agr. Bur. Plant Indust. 1913.

plant and the sensitive alfalfa plant were chosen for comparison. The effect of reaction on the reproduction of legume bacteria was studied in Ashby's mannit solution and in soil.

In Solution. The plan below was followed:

1 and 2—1.0 per cent of N/1 sulphuric acid.

3 and 4—0.5 per cent of N/1 sulphuric acid.

5 and 6—Neutral.

7 and 8—0.5 per cent N/1 sodium hydroxide.

9 and 10—1.0 per cent N/1 sodium hydroxide.

Ten 500 cc. flasks were innoculated with 1 cc. each of a water suspension of the red clover bacteria. At the end of one and two weeks plate counts were made to show the number of bacteria in each flask. It was found that a neutral or slightly acid reaction in mannit solution is most favorable for the reproduction of the red clover organism. A slight amount of alkali inhibited growth. No growth was found in the presence of one per cent normal alkali. The results of repeated counts supported the preceding statement.

Alfalfa bacteria were studied in the same manner. It was found that *Bacillus radicicola* from alfalfa grew best in a slightly alkaline or neutral solution. The optimum reaction for the growth of the alfalfa organism in mannit solution is somewhere between neutral and 0.5 per cent alkali. Unlike the organism from red clover this strain of legume bacteria was found to be very sensitive to acidity. An acid reaction of 0.5 per cent greatly retards growth. After three weeks no living cells could be found. A repetition of this experiment gave similar results.

In Soil. Twenty-five samples of sterilized Miami silt loam soil were placed in large test tubes and arranged as follows:

1 and 2—1.0 gram of $CaCO_3$ or four tons per acre.

3 and 4—0.5 gram of $CaCO_3$ or two tons per acre.

5 and 6—Neutral—untreated.

7 and 8—1.0 cc. N/1 sulphuric acid or two tons per acre.

9 and 10—2.0 cc. N/1 sulphuric acid or four tons per acre.

After treatment the soil cultures were re-sterilized and when cool, were innoculated with a pure culture of legume bacteria. Plate counts were made after one week. The figures of the counts show that calcium carbonate in all proportions benefitted the growth of *Bacillus radicicola* from alfalfa. The greatest number occurred in the soil treated with two tons of limestone per acre.

Here again, the red clover bacteria failed to show any gain in numbers in the presence of a basic substance. Large amounts of calcium carbonate retarded the growth of legume organisms from clover. Apparently red clover does best in neutral Miami silt loam soil.

Effect of Reaction on Growth and Nodule Formation of Higher Plants.—In order to test the effect of reaction on the plant and the formation of nodules it was necessary to grow the plants with a pure culture of *Bacillus radicicola*. Large test tubes were used. These contained soft filter paper pulp plus mannit solution of known reaction. The same range of reaction was used as in the experiments with solution cultures.

Figure A of Plate VIII shows the results with red clover. The plants developed best in the presence of 0.5 per cent of normal acid and even 1.0 per cent of the acid does not seriously injure growth. The nodules on the roots were carefully counted. The 0.5 per cent of acid also seemed most favorable for nodule formation. But, judging from nodule formation in the presence of alkali, it would seem that the latter was less injurious to the bacteria than to the higher plant.

Figure B of Plate VIII shows the same experiment carried out with alfalfa. An alkaline reaction seems to be favored by this plant. Not only the best growth, but also the greatest number of nodules were found in an alkaline medium. The alfalfa plant and bacteria seem to favor alkali in about the same concentration that the red clover favors acid.

These experiments were repeated in soft mannit agar and in sterilized soil. In all cases the results confirmed those cited above. The filter paper pulp furnished the best medium for the formation of nodules.

Further experimentation is needed to test the effects of different acids or to represent more closely the conditions which actually exist in an acid soil.

It is very evident from the experiments performed that alfalfa bacteria are benefitted by an alkaline reaction while the clover bacteria do best in a neutral or slightly acid medium. The difference in behavior of alfalfa and red clover plants in acid soils is characterized by a corresponding difference in the behavior of their symbiotic bacteria.

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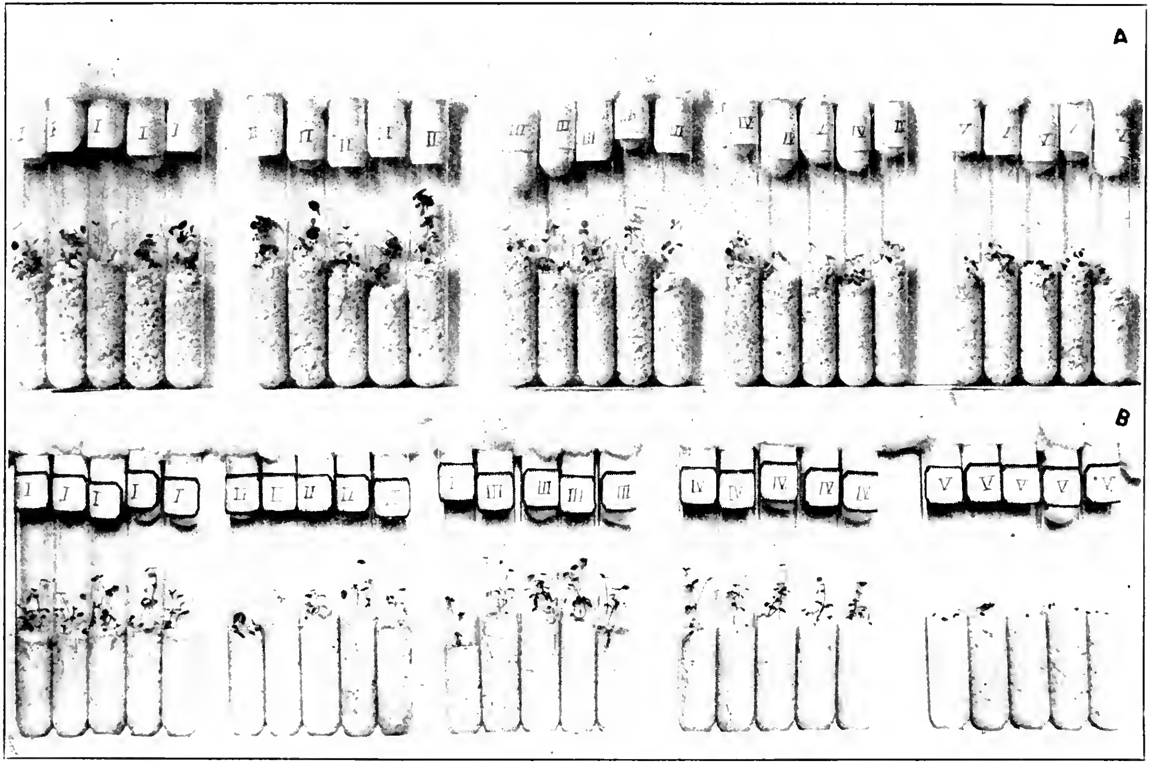

FIG. A. The Effect of Reaction of Culture Media on the Growth of Red Clover. Group I, 1.0 per cent of normal sulphuric acid. Group II, 0.5 per cent of normal sulphuric acid. Group III, Neutral. Group IV, 0.5 per cent of normal sodium hydroxide. Group V, 1.0 per cent of normal sodium hydroxide.

FIG. B. The Effect of Reaction of Culture Media on the Growth of Alfalfa. Group I, 1.0 per cent of normal sodium hydroxide. Group II, 0.5 per cent of normal sodium hydroxide. Group III, Neutral. Group IV, 0.5 per cent of normal sulphuric acid. Group V, 1.0 per cent of normal sulphuric acid.

HOW A TREE GROWS.

FRED BERNINGHAUSEN.

Professor Ebermeier of Munich, Germany says: "When the leaves take carbonic acid from the air they break it up and force its carbon into new chemical compounds which are then stored away as new material in the tree. The forest is the most highly organized portion of the vegetable kingdom."

No man can really know the forest without feeling the gentle influence of one of the kindest and strongest parts of nature. It is the most helpful friend of man.

There is no other natural agent which has done so much for the human race. Its influence upon streams alone makes farming possible. It supplies fuel, one of the first necessaries of life, and lumber, the raw material without which railroads and all the great achievements of material progress would have either been long delayed or wholly impossible.

The forest is as beautiful as it is useful. A tree is a woody plant growing up from the ground. It consists of three parts: First, the roots which take up water from the soil and some mineral substance which the tree needs in its growth; second, the trunk, stem or bole which supports the crown itself with its network of branches, buds, and leaves, in which all the food taken up by the tree from the soil and air is worked over and made ready to assist in the growth of the whole tree. The crown has more to do with the life of the tree than any other part. The most important process is the reproduction of the tree and the digestion of the food, which takes place in the crown. The material upon which the tree feeds is derived from the soil and the air. The minute root hairs take up water from the ground and with it substances which it holds in solution. These are the earthy contents of the tree which appear in the form of ashes when any part is burned. The water which contains these materials goes straight from the roots to the leaves, in which the most important process in the feeding of the tree takes place. This process is assimilation or taking up and breaking up by the leaves of carbonic gas from the air. It goes on only in the presence of light and heat and through the action of chlorophyl, a substance through which the leaves and the bark get their green color. Plants or trees containing chlorophyl are the chief means by which the mineral materials are changed into food so that nearly all plant and animal life depends upon them. Plant cells which contain chlorophyl break up the carbonic acid gas with which they come in contact, retaining the carbon, one of its elements, and sending back the oxygen into the air. Under the influence of sunlight they combine the carbon with the oxygen and hydrogen of the water from the roots into the new chemical compounds; in which nitrogen and the earthy constituents mentioned above, that is to say the food material which reaches the tree through the roots and leaves, are first digested in the body and are then sent to all living parts of the roots, stem and crown. Some of this food is stored away until the proper moment arrives. Wood is made up chiefly of carbon, oxygen and hydrogen. When perfectly dry about half its weight is carbon and half oxygen and hydrogen in almost the same proportion as water. It contains about one part in a hundred by weight of earthy constituents. The nitrogen and water taken up by the roots were originally in the air before they reached the ground. It is true therefore that when wood is burned those parts which came from the air go back into it in the form of gas, while those which came from the soil remain behind in the form of ashes. Besides giving out oxygen through the leaves to the air they breathe through the minute openings in the bark. This breathing goes on day and night and consequently more carbonic acid gas is taken into the tree than is given out and the surplus carbon is used in growing. The addition of new material or the foundation of growth is deposited in a thin coat over the whole tree between the wood and the bark. There are two layers of this coat separated by a third one of tender tissues, and the outer or cambium layer forms new bark. Wood is chiefly made up of very small tubes or cells of various kinds which have special use in the life of a tree. Some conduct water from the roots to the crown, some store away digested food, and others merely strengthen the structure of the wood and hold it together; but in each case some of the cells have thick walls and small openings and others wide openings and thin walls. Consequently at first the tree makes thin walls itself and wide openings through which water can rise rapidly to the ends of the branches; later on when the demand of water is not so great and there is plenty of digested food to supply building material the cells formed are narrow and thick walled. Thus the summer growth in wood is heavier, stronger, darker in color than spring wood.

ELDORA.

A SECTION OF UPPER SONORAN FLORA IN NORTHERN OREGON.

MORTON E. PECK.

From July 4 to July 16, 1915, the writer was stationed at Umatilla, Oregon, as special field agent of the United States Biological Survey. A part of the work assigned was the gathering of data in regard to the general character of the vegetation and the listing of the species identified. Most of the facts here given were embodied in a somewhat briefer form in the official report.

Umatilla is a small town on the south bank of the Columbia river, in Umatilla county, 110 miles from the eastern boundary of the state, and 205 miles from the Pacific coast. The elevation above sea level is less than 200 feet, and is therefore quite negligible as a climatic factor, while the Cascade mountains to the westward cut off most of the moisture from the Pacific. These conditions render the climate extremely dry and hot during the summer; moreover in June, July and August strong hot winds blow almost daily up the Columbia, greatly intensifying the general aridity. The annual precipitation is about 8.70 inches. Except along the streams, the vegetation, as might be expected, consists of only such plants as can endure rather severe xerophytic conditions.

The Umatilla river, a considerable stream, empties into the Columbia near the town. Much of the water is now being taken out by an extensive government irrigation project. Besides the Columbia and Umatilla rivers, there is very little water in the section studied except several small ponds to be mentioned presently.

Along the immediate shore of the Columbia there are in places small muddy pools and bayous, but for the most part the ground a few yards back from the margin is quite dry. There is also a little damp land along the Umatilla, which occasionally expands into small swampy strips. In many places along the banks of the latter stream there is abundant seepage.

For a distance of one-fourth to more than one-half of a mile back from the Columbia, the ground rises only from four or five to fifteen or twenty feet above the water. The soil is here loose and shifting, largely of water and wind formation. Beyond this strip of lowland the country rises rather abruptly two hundred or three hundred feet higher. This is about the mean elevation of the territory as far to the southward as our observations extended. There are higher points here and there and numerous depressions, but on the whole the country is not particularly rough.

Two or three miles southeast of the town is the end of a long lava ridge, extending for some miles to the southwestward. In many places it appears double, as if it had been upheaved and split. It rises from one hundred to two hundred feet above the general level of the country. On the eastern side of this ridge is a depression containing a chain of apparently perennial pools or ponds, none covering an area of more than an acre at the date of our visit. They are fed by small springs, and are all rather strongly alkaline.

On the west side of the Umatilla there is a considerable strip of land of about the same elevation as that lying along the Columbia. This has mostly a gradual rise to the westward.

On the whole, the area covered by these observations presents no great variety of soil conditions aside from water supply. The low strip along the Columbia and Umatilla rivers is very sandy, much of the sand being loose and shifting. It has doubtless been brought up largely from the sandy margin of the Columbia by the strong winds that blow almost constantly up stream. These winds sweep with great force across the angle formed by the confluence of the two streams on the west side of the Umatilla, and here there are many low shifting dunes. Along the lava ridge the ground is, of course, strewn with fragments of this material; otherwise throughout most of the elevated area the soil is made up mainly of water-worn gravel, fine sand, and volcanic dust. In some places the vegetation indicates the presence of a certain amount of alkali, but this is not abundant except in the above mentioned depression where the ponds are located.

Aside from water supply, probably the most important factor in determining the character of the vegetation in any of the areas we have described is the exposure to winds. Nearly all the taller plants in the less protected situations are bent very perceptibly to the eastward, the prevailing winds being from the west: this is notably true of trees and shrubs that have been planted in the town.

We will now consider briefly the various associations of plants that are found in these several situations. These forms that occur very sparingly in any locality, or are much more characteristic of one of the other associations are omitted from the list for that locality.

The species occurring along the immediate margin of the Columbia, or at least within the direct influence of the copious water supply are as follows:

Marsilia vestita	Veronica peregrina
Juncus bufonius	Verbena hastata
Salix amygdaloides	Iva axillaris
Salix exigua	Euthamia occidentalis
Polygonum emersum	Coreopsis atkinsoniana
Roripa columbiæ	Gaillardia aristata
Roripa curvisiliqua	Helenium autumnale grandiflorum
Roripa obtusa	Artemisia dracunculoides

The Marsilia is extremely abundant. The willows form low thickets in places, which are nowhere very extensive. *Roripa columbiae* is a peculiar species, of very limited distribution, apparently mainly confined to the banks of the Columbia in eastern Washington and Oregon; it is not common here. The Coreopsis, Gaillardia, Helenium, and Artemisia are especially plentiful. Several introduced plants, especially the Russian thistle and *Atriplex hastata* are common here, but are more characteristic of the next higher association. This list is a very short one, in spite of the abundance of moisture. This is due largely to the fact that the land here is nearly all below high water mark, and the late floods prevent many species from securing a foothold.

Between the moist margin of the river and the more elevated country, lies the low sandy tract above mentioned. The soil here is dry but not excessively so, and supports a fairly distinct association of plants, though several of the species are equally characteristic of the higher section. Here we find:

Oryzopsis hymenoides	Elymus condensatus
Sporobolus cryptandrus	Juncus balticus
Salsola kali tragus	Grindelia nana
Atriplex hastata	Chrysothamnus viscidiflorus
Lepidium medium	Artemisia canadensis
Gaura parviflora	Artemisia ludoviciana
Anogra pallida	Artemisia tridentata
Verbena bracteosa	

The Oryzopsis is remarkably abundant. The Russian thistle here attains its maximum size. The Chrysothamnus is extremely abundant and is quite generally distributed, while the sagebrush, though covering a more limited area, grows in places very rank. That such species as *Juncus balticus* and *Gaura parviflora* should appear in the same association as sagebrush seems a little strange. The anomaly is perhaps owing to the combination of sandy soil, hot, dry winds, and close proximity to the river. The plants of this section suffer more, it would seem, from the direct effects of the wind, than any others of the region. Species with delicate foliage cannot survive here, and low forms are likely to be buried by the drifting sand.

The vegetation of the slope leading up to the higher land is scant and mostly short, this being also much exposed to the wind. Sagebrush is here almost wanting; there is an abundance of very dwarf *Chrysothamnus viscidiflorus*, *Achillea millefolium lanulosa*, *Amsinckia intermedia*, and *Bromus tectorum*, while large areas are whitened over with *Plantago purshii*. Where there is an abundance of fine loose sand piled into low dunes by the wind, there may be found here and there large patches of *Cleome lutea* and *Psoralea lanceolata scabra*, and a scattered growth of a peculiar dune grass, *Elymus flavescens*.

The elevated section, by far the most extensive in area, did not yield a very long list of species. While the total of individual plants is sufficiently large, nearly all of them are so dwarfed as to form but a scant mantle of vegetation. Over tracts many acres in extent one may scarcely find a plant of any sort rising to a height of more than two feet. Another peculiarity of the species of this region is their "mosaic" mode of growth. One will come abruptly upon a certain form distributed in immense abundance over a considerable area of land, but when this is crossed, the species leaves off as abruptly, and perhaps another takes its place in equal profusion. Usually no particular reason for this phenomenon can be assigned. At the time of our visit the spring vegetation of ephemeral an-

At the time of our visit the spring vegetation of ephemeral annuals and weak perennials had disappeared. This, however, must have been very scant, or it would have left more traces. I was told by residents that early spring flowers were here almost wanting. The following belong in this association:

Festuca octoflora
Bromus tectorum
Agropyron subvillosum
Sitanion sp.
Comandra pallida
Rumex venosus
Polygonum majus
Eriogonum niveum
Eriogonum baileyi
Salsola kali tragus
Abronia mellifera
Sisymbrium altissimum
Kunzia tridentata
Piptocalyx circumscissus
Solanum triflorum
Nicotiana attenuata
Plantago purshii
Ptiloria paniculata
Gaertneria acanthicarpa
Lupinus ornatus
Erodium cicutarium
Linum lewisii
Euphorbia glyptosperma
Piscaria setigera
Sphaeralcea munroana
Mentzelia laevicaulis
Mentzelia albicaulis
Opuntia polyacantha
Epilobium paniculatum
Pteryxia terebenthina
Gilia inconspicua
Coldenia nuttallii
Chrysothamnus viscidiflorus
Chrysothamnus nauseosus
Erigeron hispidissimus
Balsamorhiza sagittata
Achillea millefolium lanulosa
Artemisia tridentata

This list is remarkable not only for its brevity, but also for the scant representation or total absence of a number of great genera that dominate most of the other arid sections of eastern Oregon. Among these may be mentioned Erigonum, Arabis, Astragalus, Cogswellia, Gilia, and Erigeron.

The only association that remains to be considered is that of the damp ground along the Umatilla river. We might at first thought expect to find here the same species that occur along the Columbia, but in fact we meet with not only very different forms, but a far greater variety. These are mostly Transition species which, while having plenty of moisture, are protected by their situation from the floods and winds to which those growing along the Columbia are exposed. The margins of the Umatilla, then, may be looked upon as forming a very narrow strip of Transition territory extending down to the lowest level of the Upper Sonoran that is to be found anywhere in the state. Many of the species are poorly represented, as might be expected from the smallness of the area. Even with these omitted, however, the list is very long in proportion to those of other associations. It is as follows:

Typha latifolia
Potamogeton lonchitis
Potamogeton pusillus
Alisma plantago-aquatica
Paspalium distichum
Panicum crus-galli
Phleum pratense
Polypogon monspeliensis
Sporobolus asperifolius
Agrostis alba
Agrostis exarata
Deschampsia calycina
Deschampsia elongata
Poa annua
Poa pratensis
Poa compressa
Distichlis spicata
Hordeum murinum
Hordeum jubatum
Elymus condensatus
Cyperus inflexus
Scirpus americanus
Eleocharis palustris
Eleocharis acicularis
Carex prægracilis
Carex athrostachya
Lemna minor
Juncus balticus
Juncus bufonius
Juncus tenuis
Vagnera stellata
Salix sp.
Populus trichocarpa
Alnus rhombifolia
Mentha canadensis
Verbascum thapsus
Pentstemon richardsonii
Veronica peregrina
Veronica americana
Mimulus pilosus
Mimulus langsdorfii
Mimulus floribundus
Verbena hastata
Solanum dulcamare
Solanum nigrum
Urtica holosericeus
Rumex mexicana
Rumex crispus
Polygonum aviculare
Chænopodium botrys
Alsine media
Clematis ligusticifolia
Ranunculus sceleratus
Ranunculus cymbalaria
Ribes aureum
Roripa nasturtium
Rosa pisocarpa
Potentilla rivalis
Cratægus brevispina
Thermopsis montana
Melilotus albus
Trifolium pratense
Trifolium repens
Trifolium hybridum
Trifolium sp.
Medicago lupulina
Hosakia americana
Rhus glabra occidentalis
Rhus toxicodendron
Malva rotundifolia
Hypericum scouleri
Epilobium adenocaulon
Berula erecta
Centaurion exaltatum
Lycopus lucidus
Plantago major
Galium aperine
Symphoricarpos racemosus
Agoseris heterophylla
Taraxacum taraxacum
Iva axillaris
Xanthium speciosum
Solidago serotina
Euthamia occidentalis
Bidens cernua
Gnaphalium palustre

The irrigation of a considerable tract has brought about the establishment of a number of introduced species, which are mainly confined to cultivated ground and irrigation ditches.

In concluding this brief account of the distribution of the flora in the neighborhood of Umatilla, it may be said that there are few other sections of moderate elevation in the state where the vegetation is so poor in species and so scant in quantity, and that this poverty doubtless is due to the low annual precipitation, high summer temperature, strong winds, and loose, light character of the soil. Omitting the vegetation of the river banks and cultivated ground, the flora is pronouncedly Upper Sonoran. Perhaps no better example of the zone is to be found in Oregon.

The following is a complete list of the species identified, with brief notes as to abundance, distribution, etc.

Typha latifolia L. Plentiful along the Umatilla.

Potamogeton lonchites Tuck. Rather common in the Umatilla and in irrigating ditches.

Potamogeton pusillus L. Extremely abundant in the Umatilla and in irrigating ditches. In the latter it grows in such quantities as to completely choke them up, and must frequently be cleaned out.

Alisma plantago-aquatica L. Common in mud along the Umatilla.

Paspalum distichum L. Plentiful in places on the banks of the Umatilla where there is abundant seepage.

Panicum crus-galli L. Common in damp, especially cultivated ground.

Panicum barbipulvinatum Nash. Very common along irrigating ditches.

Oryzopsis hymenoides (R. and S.) Rick. This remarkable grass is one of the most abundant of the family in this locality. It grows in large. dense tufts that apparently persist for many years. It is most plentifully distributed on the dry sandy strip bordering the immediate banks of the Columbia, but is also scattered over the high arid section.

Phleum pratense L. Frequent in moist ground.

Polypogon monspeliensis (L.) Desf. Very abundant in wet places along the Umatilla.

Sporobolus depauperatus (Torr.) Scrib. Common on gravelly bars along the Columbia. A very depressed and dwarf form.

Sporobolus cryptandrus (Torr.) Gray. Common in dry sandy places near the Columbia and Umatilla.

Sporobolus asperifolius (Nees and Mey.) Thurb. Found in abundance in a moist, slightly alkaline depression along the Umatilla.

Agrostis alba L. Common along the Umatilla and in irrigated ground.

Agrostis exerata Trin. Occasional on the margin of the Umatilla.

Deschampsia calycina Presl. Abundant along the Umatilla.

Deschampsia elongata (Hook.) Munro. Frequent along the Umatilla.

Eragrostis hypnoides (Gam.) B. S. P. Infrequent along the Umatilla.

Poa annua L. Common in damp places.

Poa compressa L. Common, with the preceding.

Poa campestris L. Common, with the preceding.

Distichlis spicata (L.) Greene. Found plentifully in several moist, more or less alkaline places.

Festuca octoflora Walt. This is one of the very abundant species over the dry elevated sections. It is very short lived and dwarfed.

Festuca megalura Nutt. Found sparingly in sandy ground near the Columbia.

Festuca elatior L. Found occasionally near the Umatilla and along irrigating ditches.

Bromus sp. An apparently native perennial in damp ground; scarce.

Bromus tectorum L. The most plentiful grass, distributed in enormous abundance over almost the entire area studied, without regard to soil or moisture conditions.

Agropyron smithii mollis (Scrib. and Sm.) Jones. In dry ground; scarce.

Agropyron subvillosum (Hook.) Piper. In dry ground; infrequent.

Hordeum murinum L. Frequent on moist banks of the Umatilla.

Hordeum jubatum L. Frequent along the Umatilla.

Hordeum nodosum L. Scarce, in moist ground near the Umatilla.

Elymus condensatus Presl. Frequent in small patches in moist places along the Umatilla, but seldom covering more than a very limited area.

Elymus sp., possibly *arenarius*. Infrequent, in loose sand.

Elymus flavescens Scribn. and Sm. A curious grass, the downy yellow spikes very conspicuous; growing rather scantily on drifting sand.

Sitanion sp. Frequent in very dry ground. A form remarkable for its dense, soft pubescence.

Cyperus inflexus Muhl. Common in wet places along the Umatilla.

Cyperus esculentus L. In moist ground; scarce.

Scirpus occidentalis (Wats.) Chase. Scarce, along the Umatilla.

Scirpus americanus Pers. Very abundant on wet margins of the Umatilla.

Hemicarpha micrantha (Vahl.) Britt. One specimen, in wet ground along the Umatilla.

Eleocharis palustris (L.) R. and S. Very abundant along the margins of the Umatilla.

Eleocharis obtusa Schult. One specimen, near the Umatilla.

Eleocharis acicularis (G.) R. and S. Common along the Umatilla.

Carex douglasii Boott. A few plants in slightly moist ground near the Columbia.

Carex praegracilis Boott. Found plentifully in one place among cat tails along the Umatilla.

Carex athrostachya Oln. Frequent along the Umatilla.

Lemna minor L. Very common along the Umatilla.

Juncus balticus Willd. Plentiful in slightly moist ground along the Columbia and less so near the Umatilla.

Juncus bufonius L. Abundant in damp ground.

Juncus tenuis Willd. Common in damp ground.

Juncus torreyi Cov. Scarce, along the Umatilla.

Juncus oxymeris Eng. Scarce, near the Umatilla.

Vagnera stellata (L.) Morong. Plentiful in one place in a damp thicket on the bank of the Umatilla.

Asparagus officinalis L. Sparingly escaped along the Umatilla.

Salix amygdaloides Anders. Abundant in places along the Columbia, reaching a height of ten to twelve feet and forming close thickets. It also occurs plentifully along the Umatilla, becoming much larger.

Salix exigua Nutt. Frequent with the preceding along the Columbia.

Salix sp. An undetermined species past fruiting; common along the Umatilla and sometimes forming close thickets.

Populus trichocarpa T. and G. Frequent along the Umatilla, and probably more so formerly. Some of these trees grow about a swampy place close to the town and have attained a good size.

Alnus rhombifolia Nutt. Rather plentiful along the Umatilla.

Celtis douglasii Planch. One or two specimens were found on a high dry slope above the Umatilla.

Urtica holosericeus Nutt. Frequent along the Umatilla, the plants remarkably tall and robust.

Comandra pallida A. DC. Common and quite generally distributed in the high arid sections.

Rumex venosus Pursh. Very plentiful in places, especially in loose, dry sand.

Rumex mexicanus Meisn. Common in moist ground along the Umatilla.

Rumex crispus L. Very common in moist ground.

Rumex persicarioides L. Scarce, in wet places along the Umatilla.

Polygonum aviculare L. Common in moist ground.

Polygonum majus (Meisn.) Piper. Common and generally distributed through the arid section.

Polygonum emersum (Michx.) Britt. Frequent in water and mud along the Columbia and Umatilla.

Polygonum lapathifolium L. Common along irrigating ditches.

Polygonum persicaria L. Common with the preceding.

Polygonum hydropiper L. Common with the two preceding.

Eriogonum niveum Dougl. Very abundant in many parts of the desert. Over considerable areas where the soil is exceptionally dry and sterile it is the dominant species. Its white color and bushy, almost leafless peduncles make it very conspicuous.

Eriogonum baileyi Wats. Moderately common in very dry ground.

Eriogonum compositum Dougl. Scarce, in dry ground. Only a few specimens found.

Eriogonum stellatum Benth. Only a few plants found in rather dry ground.

Salsola kali tragus (L.) Moq. With the possible exception of *Bromus tectorum*, this is the most abundant and generally distributed plant of our territory. It thrives from the wet margin of the Columbia to the most arid and sterile hilltops.

Atriplex hastata L. Abundant in nearly all slightly moist ground, especially along the Columbia.

Chenopodium album L. Common in all but very dry ground.

Chenopodium botrys L. Common along streams.

Abronia mellifera Dougl. Very common, especially in drifting sand.

Portulaca oleracea L. Found in abundance in a moist depression near the Columbia.

Silene menziesii Hook. In only one locality, on the bank of the Umatilla.

Alsine media L. Frequent along the Umatilla.

Tissa diandra leucantha (Robins.) Piper. Occurs rather sparingly on the margin of alkaline pools.

Clematis ligusticifolia Nutt. Frequent on the banks of the Umatilla.

Batrachium aquatile (L.) Wimm. A large flowered form was found in a pool along the Umatilla.

Ranunculus sceleratus L. Frequent along the Umatilla.

Ranunculus Cymbalaria Pursh. Abundant in wet places.

Roripa nasturtium (L.) Rusby. Common along the Umatilla.

Roripa columbiae Suks. Scarce; a few specimens found in mud along the Columbia.

Roripa curvisiliqua (Hook.) Bessey. Frequent in damp ground.

Roripa obtusa (Nutt.) Britt. Infrequent, in mud along the Columbia.

Sisymbrium altissimum L. Very abundant and generally distributed, being found nearly everywhere in the desert.

Sisymbrium canescens Nutt. Occasional along the Umatilla.

Bursa bursa-pastoris (L.) Weber. Common about houses.

Lepidium medium Greene. Abundant in slightly moist ground.

Cleome lutea Hook. One of the most conspicuous plants of the region. It grows in great abundance on drifting sand, attaining a height of five to six feet, with stems an inch in diameter.

Ribes aureum Pursh. Found in a few places along the Umatilla.

Rosa pisocarpa Gray. Common along the Umatilla.

Potentilla rivalis Nutt. Common in damp places along the Umatilla.

Potentilla permollis Ryd. One specimen, near the Umatilla.

Kunzia tridentata (Pursh.) Spreng. Common and quite generally distributed in the desert. It is mostly dwarfed and depressed.

Crataegus brevispina (Dougl.) Heller. Quite plentiful along the Umatilla, where in places it forms dense thickets.

Petalostemum ornatum Dougl. Common and generally distributed in dry ground.

Melilotus albus Desr. Extremely abundant in moist ground, especially along irrigating ditches.

Trifolium longipes Nutt. Scarce, in damp places near the Umatilla.

Trifolium pratense L. Frequent in moist ground.

Trifolium repens L. Common in moist ground.

Trifolium hybridum L. Frequent in moist ground.

Trifolium spinulosum Dougl. One specimen, in damp ground along the Umatilla. Our material seems sufficiently distinct from *Trifolium fimbriatum* to merit recognition.

Trifolium spinulosum Dougl. Frequent along the Umatilla.

Medicago lupulina L. Frequent in damp ground.

Medicago sativa L. Alfalfa is practically the only crop grown in the area under consideration. It is common as an escape wherever there is sufficient moisture.

Psoralea lanceolata scabra (Nutt.) Piper. Abundant in dry, drifting sand.

Glycyrrhiza lepidota Nutt. Common in moderately dry ground.

Hosackia americana (Nutt.) Piper. Scarce, in slightly moist ground.

Astragalus succumbens Dougl. Scarce, in dry sandy ground.

Geranium carolineanum L. Scarce, along the Umatilla.

Erodium cicutarium (L.) L'Her. Very abundant throughout the dry area.

Linum lewisii Pursh. Scarce, in moderately dry ground.

Euphorbia glyptosperma Eng. The most characteristic desert annual. Hundreds of acres are reddened over by the pecular tinge of the foliage.

Piscaria setigera (Hook.) Piper. Sparingly distributed in dry ground.

Rhus glabra occidentalis Torr. Found plentifully in one place along the Umatilla.

Rhus toxicodendron L. Occurs sparingly along the Umatilla.

Malva rotundifolia L. Common in cultivated ground.

Sphaeralcea munroana (Dougl.) Spach. Infrequent, on high dry ground.

Hypericum scouleri Hook. In a few places along the Umatilla.

Mentzelia laevicaulis (Dougl.) T. & G. In a few places on dry slopes.

Mentzelia albicaulis Dougl. Common and generally distributed in the desert.

Opuntia polyacantha Haw. Abundant in arid sections, but of uneven distribution, being quite wanting over large areas and in some places the dominant species.

Gaura parviflora Dougl. Common especially in the sandy strip along the Columbia.

Epilobium angustifolium L. One small specimen along the Columbia.

Epilobium paniculatum Nutt. Infrequent in moderately dry ground.

Epilobium adenocaulon Haussk. Very common in wet ground.

Oenothera biennis muricata (L.) Lind. Two specimens were found along the Columbia representing, apparently, two strikingly different "mutants" of this confused group.

Anogra pallida (Lindl.) Britt. An abundant and characteristic species of the low sandy strip along the Columbia.

Boisduvalia densiflora (Lindl.) Wats. Found sparingly along the Umatilla.

Myriophyllum sp. In alkaline pools; scarce.

Daucus pusillus Michx. Scarce, along the Umatilla.

Pteryxia terebinthina (Hook.) C. & R. Frequent in dry sand.

Berula erecta (Huds.) Cov. Frequent in swampy places.

Centaurion exaltatus (Griseb.) Wight. Very common in wet places.

Asclepias speciosa Torr. Scarce, in damp ground.

Asclepias mexicana Cov. Scarce, in moderately dry ground.

Phlox sp. A single specimen in dry soil.

Gilia inconspicua (Smith) Dougl. Frequent, in moderately dry soil.

Navarretia intertexta (Benth.) Hook. Scarce, in damp ground near the Umatilla.

Phacelia sp. Common in moderately dry to very dry ground.

Conanthus parviflorus Greenm. Infrequent, in dry ground.

Coldenia nuttallii Hook. Frequent in dry ground.

Heliotropium curassavicum L. Abundant in slightly moist, usually somewhat alkaline soil.

Amsinckia intermedia Fisch. & Mey. Abundant in dry soil.

Piptocalyx circumscissus (Hook. & Arn.) Torr. Scarce, in dry ground.

Marrubium vulgare L. Frequent, in moderately dry ground.

Lycopus lucidus Turcz. Common in wet ground along the Umatilla.

Mentha canadensis L. Abundant in wet ground.

Verbascum thapsus L. Common in moderately dry ground near the Umatilla.

Verbascum blattaria L. Scarce, along the Umatilla.

Pentstemon richardsonii Dougl. A remarkable and handsome species, occurring in considerable quantities on moist basaltic outcroppings along the Umatilla.

Ilysnathes dubia (L.) Bern. Scarce, along the Umatilla.

Veronica peregrina L. Common in moist places.

Veronica americana Schwein. Found sparingly along the Umatilla.

Mimulus pilosus (Benth.) Wats. Frequent along the Umatilla.

Mimulus longsdorfii Donn. Very common in wet places.

Mimulus floribundus Dougl. Frequent in wet ground along the Umatilla.

Verbena bracteosa Michx. Abundant in moderately dry ground, especially along the Columbia.

Verbena hastata L. Common in slightly damp ground, especially along the Columbia.

Solanum dulcamare L. Frequent in thickets along the Umatilla.

Solanum nigrum L. Frequent along the Umatilla.

Solanum triflorum Nutt. One of the very abundant and characteristic species of the desert; very generally distributed.

Nicotiana attenuata Torr. Very common in rather dry ground.

Orobanche comosa Hook. Found in only one place; parasitic on the roots of *Iva axillaris*.

Plantago major L. Infrequent, along the Umatilla.

Plantago purshii Roem. & Schult. Very abundant in the more arid parts, sometimes imparting a gray appearance to large areas of ground.

Galium aperine L. In one place along the Umatilla.

Sambucus glauca Nutt. In one place along the Umatilla.

Valerianella macrocera (T. & G.) Gray. In one or two places in slightly moist ground near the Columbia.

Dipsacus sylvestris Mill. Well established but not common along the Umatilla.

Cichorium intybus L. In cultivated ground; scarce.

Ptiloria paniculata (Nutt.) Greene. Common in moderately dry ground.

Symphoricarpos racemosus Michx. In one or two places near the Umatilla.

Agoseris heterophylla (Nutt.) Greene. Scarce, in moist places.

Taraxacum taraxacum (L.) Karst. Frequent, in damp ground.

Lactuca scariola integrata (Gren.) Godr. Very abundant, especially in rather dry ground along the Columbia.

Lactuca pulchella (Pursh) D. C. Scarce, along the Columbia.

Sonchus asper (L.) Hill. Frequent, in moist ground.

Iva axillaris Pursh. Abundant in slightly moist, often alkaline ground along the Columbia and Umatilla.

Xanthium speciosum Kearn. Common along the Columbia and Umatilla.

Xanthium oligacanthus Piper. Scarce, along the Umatilla. A curious species, seemingly of very limited distribution.

Gaertneria acanthicarpa (Hook.) Britt. Very plentiful in moderately dry ground.

Grindelia nana Nutt. Common along the Columbia.

Chrysopsis villosa (Pursh) Nutt. Along the Columbia; rather scarce.

Chrysothamnus viscidiflorus (Hook.) Nutt. The most abundant of the shrubby Compositæ; to be regarded as the dominant desert species. Almost universally present, and only occasionally yielding precedence to any other form.

Chrysothamnus nauseosus (Pall.) Britt. Common in the desert section, but much less so than the preceding, and often wholly wanting.

Solidago serotina Ait. Common along the Umatilla.

Euthamia occidentalis Nutt. Abundant in damp ground.

Townsendia florifer (Hook.) Gray. Scarce, in dry ground.

Erigeron hispidissimus (Hook.) Piper. Frequent in dry ground. Rays always white.

Erigeron poliospermus Gray. Though Umatilla is the type locality of this species, it seems to be very scarce, only one specimen being found. Very dry ground.

Erigeron canadensis L. Very common in moist or moderately dry soil.

Machaeranthera attenuata Howell. Scarce, in dry ground.

Lagophylla ramosissima Nutt. Frequent in moist to moderately dry ground.

Bidens vulgata Greene. Common along streams and ditches.

Bidens cernua L. Common, with the last.

Coreopsis atkinsoniana Dougl. Very common along the Columbia.

Balsamorhiza sagittata (Pursh.) Nutt. Frequent in very dry, sterile ground.

Helianthus annuus L. Frequent in moist ground.

Chaenactis douglasii (Hook.) H. & A. Infrequent, in dry soil.

Gaillardia aristata Pursh. Very common along the Columbia.

Helenium autumnale grandiflorum (Nutt.) Gray. Common along the Columbia.

Achillea millefolium lanulosa (Nutt.) Piper. Abundant throughout the arid section.

Artemisia dracunculoides Pursh. Abundant along the Columbia and in other moist places.

Artemisia canadensis Michx. Frequent along the Columbia.

Artemisia ludoviciana Nutt. Rather common along the Columbia. A form with mostly entire leaves.

Artemisia tridentata Nutt. Sagebrush is abundant but not evenly distributed, being often nearly absent in large areas. It is mostly low and dwarfed, reaching its best development on the low strip along the Columbia, and elsewhere in depressions where the moisture conditions are a little better than eommon.

Gnaphalium palustre Nutt. Common along the Umatilla.

Gnaphalium chilense Spreng. Scaree, in moderately dry plaees.

Carduus lanceolatus L. Common in moist ground.

Carduus undulatus Nutt. Found in rather dry ground in only a few plaees.

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A SEED KEY TO SOME COMMON WEEDS AND PLANTS.

E. L. PALMER.

INTRODUCTION.

The aim of this thesis is three-fold. Primarily, it is written to furnish a method of determining accurately the names of various seeds and seedlike fruits with the express purpose of detecting adulterants in commercial seeds. The key should also aid in determining plants in the fruiting condition when the flower parts are too far advanced for identification by the ordinary method. Further, it should serve as a check to determinations from a study of the flowers.

The terms "weeds" and "seeds" may be variously interpreted. A weed has been defined as "a plant out of place" or better still as a "useless or troublesome plant." Using the latter interpretation, the author chose those plants which were listed as troublesome weeds in the publications of various agricultural experiment stations. A few other wild plants were added and as special attention was paid to the adulterants of the seeds of Red Clover, White Clover, Alsike Clover, Alfalfa, Timothy, and Red Top, these seeds were inserted in the key. The term "seeds" was interpreted in the broad sense and includes not only true seeds but seedlike fruits such as are found on *Taraxacum officinale* Weber (Dandelion), *Arctium minus* (Burdock); etc. The botanical nomenclature used is the same as that found in the seventh edition of "Gray's New Manual of Botany" 1908.

LITERATURE.

Quite a few publications have been made in connection with seed study. The work of Harz seems to be the most thorough of these. It deals principally with the anatomy, histology and chemical properties of various seeds. The bulletin of W. J. Beal entitled "The Seeds of Michigan Weeds," 1910, gives accurate descriptions of the more common weeds of Michigan. Excellent illustrations by Mr. F. H. Hillman serve as a check to the descriptions. Mr. Hillman also is the author of Farmers' Bulletin 428, 1911, U. S. D. A., which gives valuable lists of adulterants of commercial seeds. He also has published numerous other bulletins but the author considers the above mentioned the most comprehensive. "The Seeds of the Blue Grasses," Bulletin 84 of Bureau of Plant Industry, U. S. D. A., 1905, by Edgar Brown and F. H. Hillman, includes a key to the seeds of six species of Poa as found in commercial seeds. Aside from this last mentioned paper, no literature has been found which concerns itself with a key which will aid in the systematic determination of different seeds.

METHODS OF STUDY.

The specimens studied were collected for the most part during the summer and fall of 1911. These were carefully labelled with the common and scientific names. An attempt was then made to describe each seed carefully, using the external characters which were most evident with the use of an ordinary hand-lens. From these descriptions and with the use of the specimens constantly for reference, the key was constructed. Drawings were used in preference to photographs because it was believed that by them the distinguishing characters could be brought out to a better advantage. The seeds of the grasses were described as they appear with the glumes or scales removed, at least where these are easily removed by rubbing between the thumb and fore-finger. Seeds vary considerably and where there was any doubt as to which one of two descriptions would serve, the seed was entered under both headings. In this way the opportunities of misinterpretation were minimized. A given seed may be entered many times, due to its variations. This might appear to be a bad condition of affairs and lead one to believe that better distinguishing characters might have been chosen. A trial of the key in actual testing, however, should prove to the individual that the arrangement into distinct groups according to size facilitates the quick determination of a seed. It should be noted that even in the most complex instance but twenty steps are required to make the determination.

THE USE OF THE KEY.

To secure satisfactory results, the key should be used with the drawings as a guide to correct interpretation. To determine a given seed, first rub it vigorously between the thumb and fore finger to remove any loose scales or flower parts which may be adhering. Now determine the length in milimeters exclusive of any *fragile* terminal appendage and turn to the group which would include a seed of that length. In this group are two other groups numbered (II). Determine in which of these the seed belongs and continue in a like manmanner until the name of the seed is found. If any character is not plain turn to the picture of a seed described as having that character.

The writer wishes to thank Prof. W. W. Rowlee, Dr. H. B. Brown and Mr. H. P. Brown for advice and criticism during the progress of the work.

Descriptions of Seeds Given in the Key.

Abbreviations: (L)=Length; (W)=Width; (C)=Color; (S)=Shape; (O)=Occurence as an adulterant.

1. *Digitaria sanguinalis* (L.) Scop. Crab Grass, Finger Grass. L. 1.8—2.2 mm. W. .6—.8 mm. C., light straw to brown or dull green. S., broad spindle shaped to blunt especially at the base; boat shaped; the scar on one side running about one-half the length of the seed: outer chaff usually present, the outer scale being as long as the seed and three-ribbed, the inner about one-half the length of the seed. "Edges of floral groove smooth" Beal. O., sometimes very troublesome, common in clover grass and alfalfa seeds. Introduced from Europe. For drawing see Harz p. 1258, fig. 166, XXIII-XXV.

2. *Panicum capillare* L. Old Witch Grass. Tickle Grass, L. 1.2— 1.8 mm. W. .8—1.5 mm. C., greenish yellow, glossy, dark in the middle and lighter at the ends. S., oval to elliptic and slightly flattened; glume with five fine longitudinal nerves, inner glume with two fine longitudinal lines. O., a common tumbleweed, common in alfalfa and the grasses; rather unimportant. Native.

3. *Echinochloa cruss-galli* (L) Beauv. Barn-yard Grass. L. 2.2— 3.2 mm. W. 1.3— 2.8 mm. C., shining gray brown to

straw colored. S., oval in outline with one side flat and the other convex; surface smooth. O., common, especially on waste ground, in gardens, etc. Native.

4. *Setaria glauca* (L) Beauv. Yellow Fox-tail, Pigeon Grass. L. 2.5— 3.4 mm. W. 2.—2.8 mm. C., dark brown or straw colored. S., flattened oval, tapering almost equally at each end: one side flat or sometimes slightly concave, the other side quite convex. The concave side has coarser ridges, the flat side being occupied by a sunken area. At one end, a slight elevation is evident. Surface covered with minute lateral striations. The extremities are blunt and the seed is widest at the middle. O., very common in gardens, bothersome; commonly found in alfalfa, red clover and many other kinds of farm seeds. Introduced from Europe.

5. *Setaria viridis* (L) Beauv. Green Foxtail, Bottle-grass, Green Pigeon Grass. L. 1.8— 2.5 mm. W. 1.2— 2. mm. C., dull pale green to gray-brown often mottled with black. S., oval, flattened on one side and concave on the other; surface with fine longitudinal and transverse striations and a small rounded projection at the basal end: resembles *Setaria glauca* but is smaller and differs in that the flat side lacks the sunken area. O., common in many farm seeds much the same as *Setaria glauca*. Especially common in alfalfa, timothy and red clover seeds. Introduced from Europe.

6. *Phleum pratense* L. Timothy, Herd's Grass, L. 1.2— 1.8 mm. W. .7— 1. mm. C., light straw to yellow. S., broad fusiform with the base slightly oblique and the surface reticulated with oblong ridges or shallow pits. O., common in grass lands, cultivated. Introduced from Europe.

7. *Agrostis alba*. L. White Marsh Bent Grass, Red Top, Herd's Grass, Fiorin. L. .8— 1.2 mm. W. .4— .7 mm. S., spindle shaped, almost elliptical, broad with one end pointed and the other rounded; scar short and rounded and not more than ¼ the length of the seed: palea two-nerved and lemma three-nerved, nearly equalling the glumes. O., common in grass lands and cultivated. Introduced from Europe. See Harz, p. 1262, fig. 167, I-IV.

8. *Eragrostis megastachya* (Koeler) Link. Stink Grass, Snake Grass. L. .4—.8 mm. W. .3—.5 mm. C. red-yellow

to dark brownish red. S., broadly oval and slightly flattened with each end slightly pointed; very finely netted with dark lines. O., common in waste land. See Beal. Fig. 15. Introduced from Europe.

9. *Poa pratensis* L. June Grass, Spear Grass, Kentucky Blue Grass. Length of floret 3.0— 4.4 mm., of the seed 1.1— 1.5 mm. Width of seed .4— .8 mm. C., light brown. S., equally three-sided in cross section with a shallow groove on one side; surface finely hairy at the angles; angles quite distinct; quite long and attenuate at the apex. Introduced from Europe.

9a. *Poa compressa* L. Canada Blue Grass. This grass very closely resembles *Poa pratensis* L. and is used as an adulterant of the same. According to Hillman and Brown, Bull. 84, U. S. D. A., Bureau of Plant Industry, it differs principally in that the intermediate veins of the glumes are distinct in *Poa pratensis* L. and indistinct in *Poa compressa* L.

10. *Glyceria nervata* (Willd) Trin. Fowl Meadow Grass, Beard Grass. L. .6— 1. mm. W. .4— .5 mm. C., black with silvery reticulations. Very broadly elliptic or spindle-shaped with a short acutely tipped apex; base with a short blunt tip; surface irregularly wrinkled. O., common in marshy regions; found in seeds of alsike clover. Introduced from Europe.

11. *Bromus secalinus* L. Chess, Cheat. L. 5.8— 7.2 mm. W. 2.2—2.9 mm. C., dark brown or flesh colored. S., oval, at least in general outline, very deeply heart-shaped in cross section or spindle-shaped with a broad very deep groove up one side: "floral glume rounded on the back and obscurely seven nerved; palea with a single row of stiff hairs; club-shaped rachilla distinguishes it from the cultivated grasses." Hillman. O., common in seeds of cereals and large seeded grasses especially in orchard grass; sometimes found in the clovers. See Beal, fig. 7. Introduced from Europe.

12. *Laportea canadensis* (L) Gaud. Wood Nettle. L. 2.8— 3.8 mm. W. 2.5— 3. mm. C., dark brown to black. S., almost circular but with two short projections on the edge rather near each other but diverging, pronouncedly flattened. O., not a bad weed in crops but common in lowlands. Native.

13. *Rumex crispus* L. Narrow-leaved or Curled Dock. L. 1.2— 2.2 mm. W. .7— 1.4 mm. C., dark brown to reddish

brown. S., triangular in cross section with acute angles; abruptly obtuse at the base and rather attenuate at the apex (not as attenuate at the apex as *Rumex obtusifolius*). O., the commonest Rumex in farm seeds, found chiefly in blue grass, orchard grass and red clover. Introduced from Europe.

14. *Rumex obtusifolius.* L. Broad leaved or Bitter Dock. L. 1.8— 2.4 mm. W. .8— 1.4 mm. C., light reddish brown or tan and shining. S., triangular in cross section; rather attenuate at the apex and more contracted at the base; sides convex or slightly so; angles near the base slightly concave, near the apex convex. O., sometimes found in farm seeds. Introduced from Europe.

15. *Rumex Acetosella* L. Field or sheep sorrel. L. 1.2—1.8 mm. W. .8 —1.4 mm. C., shining reddish brown. S., three-sided in cross section, abruptly tapering to a point at the apex and rounded at the base; angles rounded and sides convex. O., common in red clover, orchard grass and timothy. Native.

16. *Polygonum aviculare* L. Knot Grass, Knot-weed. L. 1.8—2.4 mm. W. .8—1.4 mm. C., dull reddish brown. S., unequally three-sided, tapering at the apex to a long acuminate but at length rounded point; base moderately tapering to a rounded point; angles rather abrupt and rounded; surface finely granular in longitudinal striations. O., of minor importance as a field weed although often found as an adulterant of red clover. Native.

17. *Polygonum Persicaria* L. Lady's Thumb. L. 2.—2.8 mm. W. 1.7—2. mm. C., shining jet black. S., broadly oval or round with a short point at the apex and a short projection at the base; flattened, although the faces are more or less concave. O., common in various kinds of farm seeds especially in red clover. Introduced from Europe.

18. *Polygonum virginianum* L. Virginia Knotweed. L. 3.4—4.4 mm. W. 1.8—2.4 mm. C., shining chestnut brown. S., chestnut shaped but more attenuate at the base, oval in general outline; surface smooth and highly polished. O., common in low and waste grounds. Native.

19. *Polygonum Convolvulus* L. Wild Buckwheat, Black Bindweed. L. 2.5—3.5 mm. W. 1.8—2.3 mm. C., dull jet

black. S., triangular in cross section tapering at both ends to a somewhat attenuate point; faces somewhat concave. O., common in all kinds of farm seeds from all sources, particularly in the seeds of cereals, millet and flax. Introduced from Europe.

20. *Polygonum scandens.* L. Climbing False Buckwheat. L. 3.5—7.2 mm. W. 3.—4.8 mm. C., shining jet black. S., triangular in cross section, tapering almost equally at each end to a point; faces slightly concave; angles slightly rounded. O., not common. Introduced from Japan.

21. *Chenopodium hybridum* L. Maple-leaved Goosefoot. L. 1.2—2.2 mm. W. 1.2—2.2 mm. Thickness .4—.6 mm. C., shining black or gray. S., almost round with a shallow notch on one side; sides equally convex; a groove on one side leading from the notch to near the center. O., not very common, but often found on waste land. Native.

22. *Chenopodium album* L. Lamb's Quarters, Pigweed. L. 1.—1.5 mm. W. .8—1.5 mm. C., dull black or shining or gray. S., circular except for a notch on one side; one face nearly flat, the other convex; the edge rounded. O., common in all kinds of farm seeds particularly clover and grass seeds. Introduced from Europe.

23. *Atriplex patula* L. Spreading Orache. L. 1.3—1.9 mm. W. 1.4—1.7 mm. C., black or dull dark gray speckled with light gray when the involucre is on; shining black with the involucre off. S., nearly circular with a slight notch on one side; face nearly flat; groove on one side running from the scar towards but not to the center. O., not common. Introduced from Europe.

24. *Amaranthus retroflexus* L. Rough Pigweed. L. .8—1.2 mm. W. .6—.9 mm. C., shining jet black or reddish if immature. S., obovate or broadly oval with a slight notch at one side of the narrower end; smooth surface very finely reticulated with fine lines when seen with a low-power microscope. "When seen edgewise the hem-like margin in this seed is less prominent than in *A. graecizans, A. hybridus* and *A. blitoides.*" Beal. O., common in various kinds of farm seeds, especially clover and timothy.

25. *Amaranthus hybridus* L. Slender Pigweed. L. 1.—1.5 mm. W. .8—1.4 mm. C., shining black unless immature and

then reddish or purplish. S., broadly ovate or nearly circular; more pointed than *A. graecizans;* notch on one side of the narrower end; thickest in the middle, curving convexly to a rather acute angle. O., not important; introduced from Tropical America.

26. *Amaranthus graecizans* L. Tumble-weed. L. .6—1. mm. W. .4 —1.mm. Thickness about .3 mm. C., shining jet black. S., nearly circular, thick at the middle and tapering to a rather acute angle at the edge; a notch on one side and fine reticulations on the surface. O., common in farm seeds, especially clover. Introduced from Tropical America.

27. *Spergula arvensis* L. Spurry. Corn Spurry. L. 1.2—1.8 mm. W. 1.2—1.6 mm. C., black with a narrow yellowish wing and a few short yellowish spines. S., broadly lens shaped with a slight notch on one side, often with two notches close together at the hilum; surface with very minute shallow pits. O., found in grain fields and light sandy soil. Naturalized from Europe.

28. *Arenaria serpyllifolia* L. Thyme-leaved Sandwort. L. .3—.5 mm. W. .2—.4 mm. Thickness .2—.3 mm. C., grayish black or reddish brown, somewhat lead-colored. S., almost circular with the exception of a notch at one side; surface covered with about seven concentric or eccentric rows of oval-shaped elevations on each side. O., common in sand soil and found in many farm seeds. Introduced from Europe.

29. *Stellaria media* L. Cyrill. Common Chickweed. L. .8 —1.2 mm. W. .6—.9 mm. C., reddish yellow to brown. S., disc-shaped, round, almost as thick at the edges as at the center; surface covered with concentric rows of tubercle-like projections; a slight notch at one side at the scar. O., very common especially in imported and domestic clover seeds. Naturalized from Europe.

30. *Cerastium viscosum* L. Mouse-ear Chickweed. L. .6— .8 mm. W. .4—.6 mm. C., reddish yellow-brown with less red than in *Stellaria media.* S., somewhat circular or disc-shaped but quite angled, somewhat wedge-shaped; surface covered with concentric rows of tubercle-like projections more pronounced than in *Stellaria media.* O., common in small clover and grass seeds, "particularly in alsike and timothy from Canada" (Hillman). Introduced from Europe.

31. *Agrostemma Githago* L. Corn Cockle. L. 2.8—3.5 mm. W. 2.5—3.3 mm. C., dark brown to black. S., irregularly round with two broad shallow grooves following the outline of the cotyledons, quite angular; surface covered with numerous (about thirty) rows of short rounded elevations. O., "common in seeds of cereals, millets, vetches and flax from all sources" (Hillman). Introduced from Europe.

32. *Lychnis alba.* Mill. White Campion. L. 1.2—1.8 mm. W. 1.2—1.4 mm. C., dusty yellow with numerous black topped tubercles. S., short kidney-shaped with about fifteen rows of tubercles on each side, base of tubercles not notched as in *Silene noctiflora* L. O., rather common along roadsides. Introduced from the Old World.

33. *Silene noctiflora* L. Night-flowering Catch-fly. L. 1.2—1.8 mm. W. 1.—1.3 mm. C., gray-brown with a slight reddish or pink tinge. S., very short kidney-shaped; flattened especially on one side; surface covered with concentric rows of glandular-like structures. O., common and often abundant in seeds of red and alsike clovers. Introduced from Europe.

34. *Saponaria officinalis* L. Soapwort or Bouncing-Bet. L. 1.8—2.4 mm. W. 1.8—2.4 mm. C., dark bluish black. S., short kidney-shaped to circular with a notch on one side; surface covered with concentric rows of tubercle-like projections. O., sandy land and roadsides; in various farm seeds. Naturalized from Europe.

35. *Portulaca oleracea* L. Purslane, Pussley. L. .5—.8 mm. W. .3—.6 mm. C., shining black or sometimes with a purplish tinge. S., broadly ovate, flattened; sometimes almost circular but usally quite pointed near the scar; surface covered with numerous shallow cavities; one large cavity running from the scar back along the seed. O., very common in gardens and in waste lands. Introduced from the southwest.

36. *Ranunculus abortivus.* L. Small flowered Crowfoot. L. .8—1.4 mm. W. .6—1.2 mm. C., light yellowish brown. S., lenticular in cross section, slightly winged around the margin: a beak at the end short and curved; surface wrinkled radially around the margin. O., not particularly common but very abundant in certain regions. Introduced from Europe.

37. *Ranunculus acris* L. Tall Crowfoot or Tall or Bitter Buttercup. L. 2.5—4. mm. W. 2.5—3.5 mm. C., dark brown

or yellowish brown. S., obovate or ovate with a slight curved beak at the apical end and a narrow wing around the edge; base set obliquely to the longitudinal axis of the seed; one side convex, the other nearly flat; thin. O., common in lowlands and fields. Introduced from Europe.

38. *Lepidium ruderale* L. Pepper Wort, Pepper Grass. L. 1.4—1.8 mm. W. .6—1. mm. C., tan to yellow-brown. S., obovate, narrowly winged; narrower at the apical end thus differing from *Arabis laevigata;* with a groove running down each side from the scar. O., common in clovers and grasses. Introduced from Europe.

39. *Capsella Bursa-pastoris.* L. Medic. Sheperd's Purse L. .5—1.2 mm. W. .2—.8 mm. C., yellow to reddish brown. S., flattened oblong with a longitudinal groove running in a loop from the base for nearly the whole length of the seed. O., common in white, alsike and red clovers, also in blue grass, a pest in alfalfa. Introduced from Europe.

40. *Brassica nigra.* (L) Koch. Black Mustard. L. 1.—1.8 mm. W. 1.—1.6 mm. C., dark reddish brown with a network of lighter lines. S., only slightly flattened sphericalk; sometimes a trifle angular; surface pitted and covered with a network of ridges. O., found in clovers and grass seeds. Introduced from Europe.

41. *Sisymbrium officinale* (L) Scop. Hedge Mustard. L. .8—1.5 mm. W. .3—.8 mm. C., tan or yellowish, greenish brown. S., quite irregularly oval to oblong, usually more blunt at the apical end and tapering at the base; a curving line from the scar down one side follows the outline of the cotyledons. O., a rather common weed. Introduced from Europe.

42. *Barbarea vulgaris.* R. Br. Common Wild Mustard. L. .8— 1.7 mm. W. .6— 1.2 mm. C., light brown shining slightly under the microscope. S., flattened oval, irregular and with a distinct elevation at the scar; surface sparingly covered with a network of fine ridges or pits. Differs from *Brassica nigra* in being lighter in color, flatter and in having less pronounced ridges or pits. O., common in fields and gardens and in many seeds. Introduced from Europe.

43. *Arabis laevigata* Muhl Poir. Rock Cress. L. 1.5— 1.8 mm. W. .8— 1. mm. C., tan to yellow-brown. S., flattened oval to oblong with a small hook at the blunt end; with a

groove extending from the hook back along the sides showing the location of the cotyledons; winged around the margin; broadest toward the apical end. O., not a remarkably bad weed but rather common. Native.

44. *Potentilla monspeliensis* var *norvegica* L. Rydb. Cinquefoil, Five Finger. Length .6— 1. mm. W. .6— .9 mm. C., light yellowish brown sometimes slightly shining. S., nearly round except for a short straight area on one side; sometimes flattened and lens-shaped in cross section; surface covered with numerous forked ridges or wrinkles. O., common in alsike clover and in timothy. Introduced from Eurasia.

45. *Agrimonia striata* Michx. Tall Agrimony. Length of fruit 5. —10. mm. including the hooked prickles. W. 4. —8. mm. C., reddish brown. S., turbinate or top-shaped with a crown of hooked prickles; lower part with about fifteen longitudinal flutings; fruit two-celled and two-seeded; the lower part slightly hairy. O., not a bad weed. Introduced from Eurasia.

46. *Trifolium pratense* L. Red Clover. L. 1.5— 2. mm. W. 1.— 1.4 mm. C., light yellowish to bluish brown. S., somewhat triangular to ovoid; flattened; scar near the center of one edge; differs from *Medicago lupulina* in not having the prominent elevation at the scar. O., cultivated. See Hillman. Introduced from Europe.

47. *Trifolium repens.* L., White Clover. L., .8— 1.4 mm. W., .8— 1.1 mm. C., yellow to brownish red. S., somewhat shield-shaped; flattened; with a groove extending for a short distance from the straight or concave end; one end rounded. O., cultivated. Introduced from Eurasia.

48. *Trifolium hybridum* L. Alsike Clover. L., .8— 1.6 mm. W., .5—1.4 mm. C., dark yellowish green to black. Shape, almost identical in shape with *Trifolium repens* differing from it principally in the color. O., cultivated. Introduced from Europe.

49. *Melilotus alba* Desr. White Melilot or Sweet Clover. L., 2.—2.4 mm. W., 1.2—1.5 mm. C., dull greenish brown to greenish yellow, usually quite light colored. S., smooth and very nearly truly elliptical, with a broad shallow notch near one end; has a peculiarly sweet odor. O., found in alfalfa and red clover. Introduced from Europe.

50. *Medicago sativa* L. Alfalfa, Lucerne. L., 1.8—2.5 mm. W., 1.—1.4 mm. C., greenish yellow to brown. S., kidney-shaped to diamond-shaped with edges less rounded than in *Melilotus alba;* slightly thinner and larger than *Medicago lupulina* and without the prominent elevation near the scar. O., widely cultivated. Introduced from Europe.

51. *Medicago lupulina* L. Yellow Trefoil, None-such, Black Medick. L., 1.5—2.4 mm. W., .7—1. mm. C., yellowish green or brown. S., flattened oval especially near the scar; with an elevation near the scar extending beyond the general outline of the seed. O., found especially as an adulterant in alfalfa. Introduced from Europe.

52. *Amphicarpa monoica* (L.) Ell. Hog Peanut. L., 4.2—5.8 mm. W., 3.2—4.8 mm. C., purplish black mottled with gray. S., short flattened oval with the hilum on the edge; surface smooth. O., not a bad weed; common in thickets growing over other weeds. Native.

53. *Rhus Toxicodendron* L. Poison Ivy. L., 3.—5.8 mm. W., 2.8—5. mm. C., white or nearly so. S., fruit nearly globular, seed somewhat kidney-shaped with two flutings on each side. O., common in rocky and swamp places, shrubby or climbing; poisonous. Native.

54. *Impatiens biflora* Walt. Spotted Touch-me-not. L., 3.8—5.8 mm. W., 2.—3.5 mm. C., usually quite dark reddish brown. S., oval with a slight beak on one end and four or sometimes five narrow longitudinal ridges on the sides; somewhat flattened with two ridges on the outer face and one down each face; surface somewhat wrinkled. O., common in damp places and spreading quite rapidly. Native.

55. *Abutilon Theophrasti.* Medic. Indian Mallow, Velvet Leaf. L., 3.2—4.4. mm. W., 2.6—3.4 mm. C., graying brown. S., somewhat kidney-shaped to ovoid; resembling Datura but having a much more pronounced notch; flattened. O., flat waste lands and in pastures. Introduced from India.

56. *Malva rotundifolia* L. Common Mallow, Cheeses. L., 1.2—2.2 mm. W., 1.2—1.8 mm. C., light greenish brown. S., nearly circular except for a notch on one side; flattened and slightly thinner on the side next the notch; seeds borne in disc-like fruits. Introduced from Europe.

57. *Malva moschata* L. Musk Mallow. L., 1.8—3.2 mm. W., 1.6—3. mm. C., fruit dark gray or brown appearing silvery because of numerous hairs, seeds resembling *Malva rotundifolia* but lighter in color. S., short kidney-shaped or circular with a notch on one side and a space of apparently different texture in the center. O., common in fields and meadows. Introduced from Europe.

58. *Hypericum perforatum* L. Common Saint John's Wort. L., .5—1.2 mm. W., .2—.5 mm. C., dark brown, shining. S., abruptly tapering or rounded at the ends; cylindrical; surface covered with longitudinal rows of minute (about twenty in a row), indented scales or rectangular markings. O., very common and troublesome. Introduced from Europe.

59. *Oenothera biennis* L. Common Evening Primrose. L., 1.1—2.2 mm. W., .5—1.5 mm. C., brick red. S., very irregularly 4—6 sided, usually sharp angles and flat faces; angles often winged; surface minutely ridged or wrinkled. O., quite common in pastures, common in timothy and found in clover. Native.

60. *Carum Carvi* L. Caraway. L., 2.8—4.4 mm. W., .7—1.4 mm. C., rich yellowish red with six lighter longitudinal ridges. S., somewhat fusiform with one side slightly concave and the other broadly convex; with six longitudinal ridges. O., not a bad weed, sometimes cultivated. Introduced from Europe.

61. *Daucus Carota* L. Wild Carrot. L., 1.5—4.8 mm. W., .8—2. mm. C., light greenish brown with lighter stripes. S., flattened hemispherical, oval, with a row of frail edges along the acute edges and from two to five rows of still more frail spines running from end to end on the convex surface; very variable in size and shape; in commercial seeds the spines are often rubbed off. O., common in red clover and in imported alfalfa seeds. Introduced from Europe and spreading rapidly.

62. *Asclepias syriaca* L. Common Milkweed. L., 6.—8. mm. including the wing. W., 3.—4.2 mm., including the wing. Thickness. .8—1.2 mm. C., light reddish brown. S., ovate, much flattened; the base abruptly truncate; one side slightly concave and bearing a slight keel in the center extending for about one-half the length of the seed; with minute appressed hairs. O., troublesome in pastures.

63. *Cuscuta Gronovii* Willd. Gronovius Dodder. L., 1.4—1.9 mm. W., 1.2—1.8 mm. C., dark brown, granular, dull, sometimes yellowish. S., almost globular, closely resembling clover seed but more close and compact; embryo in a spiral; without a noticeable concavity at the scar. O., very common in lowlands. Native.

64. *Cuscuta epithymum* Murr. Clover Dodder. L., .6—1.2 mm. W., .7—1. mm. C., variable, usually dusty light brown to black. S., irregularly spherical with distinct shallow pits when seen through a hand microscope; usually with a fairly distinct scar at point of attachment; often with two adjacent flattened areas near the scar. O., quite common in clover and alfalfa.

65. *Cuscuta arvensis* Beyrich. Field Dodder. L., 1.—1.8 mm. W., .8—1.5 mm. C., quite light pinkish yellow or flesh colored, rarely dark brown; with a grayish dusty appearance under the microscope. S., irregularly spherical; almost invariably with two or three adjacent flattened areas on one side and with the other side rounded regularly. Surface of a granular appearance. Embryo curled. Surface not prominently pitted as in *C. epithymum* Murr. Much lighter in color than *C. Gronovii* Willd. O., found occasionally in red clover. Introduced from Europe.

66. *Lappula virginiana* (L.) Greene. Stickseed, Beggar's Lice. L., 3.—4.4 mm. W., 2.—2.9 mm. C., dark brown to black. S., broadly ovate with spines on one side and about four ridges radiating from an ovate ridge on the other, spines with bulbous tips. O., abundant along roadsides and found as an adulterant of red clover seed. Native.

67. *Lithospermum arvense* L. Corn Gromwell, Wheat Thief, Red Root, Stoneseed. L., 2.5—3.8 mm. W., 1.8—2.2 mm. C., light gray-brown with a dark area at the base, dull. S., turbinate or somewhat spherical with a long drawn out protuberance at the apical end and a slight keel on the back surface; base truncate with two minute tubercles visible to the naked eye; very hard. O., found in seed of red clover, alfalfa, cereals, grasses, etc. Naturalized from Europe.

68. *Verbena urticaefolium* L. Nettle-leaved Vervain. L., 1.5—2.2 mm. W., .5—.9 mm. C., dull dark reddish brown with a pronounced white spot at one end. S., oval to oblong.

somewhat four-angled, shorter and broader than *Verbena hastata*. O., common along roadsides and found as an adulterant of red clover. Native.

69. *Verbena hastata* L. Blue Vervain. L., 1.7—2.4 mm. W., .4—.7 mm. C., dull reddish brown. S., oblong to cylindrical; one side very convex and with about five narrow longitudinal ridges, the other side made up of two plane faces set at an angle of about 40 degrees and with a white scar at one end; shorter and broader than *Verbena urticaefolium*. O., common in some clovers. Native.

70. *Nepeta Cataria* L. Catnip, Cat Mint. L., 1.3—1.7 mm. W., .8—1.2 mm. C. and S., dull red with two oval-shaped white cavities placed end to end near one end of the seed, the cavities being filled with a white cottony substance; broadly oval and slightly compressed. O., very abundant but not dangerously common in clover seeds. Introduced from Europe.

71. *Prunella vulgaris* L. Self Heal, Heal All, Carpenter Weed. L., 2.—2.6 mm. W., .9—1.2 mm. C., shining light or dark brown. S., slightly flattened oval tapering at one end to a small triangular whitish appendage; with two dark longitudinal lines on each side. O., one of the commonest impurities of clover, alfalfa and grass seeds. Introduced near Washington from Europe.

72. *Leonurus Cardiaca* L. Common Motherwort. L., 2.—2.5 mm. W., .8—1.2 mm. C., light or dark brown. S., one side rounded, two sides plane with the apex of the seed broader than the base. O., common in waste places. Introduced from Europe.

73. *Datura Stramonium* L. Stramonium, Jimson-weed, Thorn Apple. L., 3.—3.8 mm. W., 1.7—2.2 mm. C., dark brown. S., flattened oval with irregular elevations and pits; one edge nearly straight, the rest curved. O., found quite commonly in waste places; poisonous. Introduced from Asia.

74. *Verbascum Thapsus* L. Common Mullein. L., .5—1. mm. W., .4—.7 mm. C., usually dark brown, sometimes light. S., somewhat cylindrical but of a slightly smaller diameter at the apical end; surface covered with oval grooves or pits. "The pitted surface seems to predominate in *Verbascum Blattaria*

while the grooved surface seems to be more common in *Verbascum Thapsus.*" Beal. O., very common in meadows and pastures. Introduced from Europe.

75. *Verbascum Blattaria* L. Moth Mullein. (See description of *Verbascum Thapsus.*)

76. *Linaria vulgaris* Hill. Butter and Eggs, Ramsted, Toad-flax. L., 1.5—2.1 mm., including wing. W., the same. Thickness about .2—.3 mm. C., dark grayish brown to black. S., flat and circular with a broad wing around the margin; wing marked with very fine radiating lines; surface with numerous rounded elevations. O., a bad weed in grass lands and pastures. Introduced from Europe.

77. *Plantago major* L. Common Plantain, Broad-leaved Plantain. L., 1.—1.8 mm. W., .5—1.2 mm. C., variable shades of yellow, brown and black. S., very variable, oblong, pyramidal, oval or rhomboidal with minute waving markings. O., very common in door yards and found in red clover seeds. Introduced from Europe.

78. *Plantago Rugelii* Dcne. Rugel's Plantain. L., 1.5—2.7 mm. W., .6—1. mm. C., dull dark brown to black. S., very variable; flattened variously with rather acute angles and no regular markings, although the surface is finely granular or roughened. O., a bad weed, especially in clover and timothy, also in redtop. Native.

79. *Plantago lanceolata* L. Rib-grass, Ripple Grass, English Plantain, Narrow-leaved Plantain and Buckhorn. L., 2.—2.8 mm. W., .8—1.2 mm. C., shining amber-brown to black. S., allantoid in cross section, tapering at the ends; elongate saucer-shaped with a deep crease running down one side. (See fig. XV.) O., very common in grass seed, alfalfa and red clover. Introduced from Europe.

80. *Dipsacus sylvestris* Huds. Wild Teasel. L., 3.—4.2 mm. W., .8—1.3 mm. C., dark or light grayish brown and finely hairy. S., oblong; nearly square in cross section, with three rounded ridges on each side which unite at the apex; apex slightly hollowed with a tubercle-like projection in the center, base corrugated. O., common in lowlands and pastures. Naturalized from Europe.

81. *Eupatorium purpureum* L. Joe-Pye Weed, Trumpet Weed. L., 2.8—3.3 mm. W., .4—.6 mm. C., dark greenish

brown. S., oblong, four-angled in cross section; contracted at the base to a sharp point; rather thickly dotted with particles of resin-like matter. O., common in lowlands. Native.

82. *Eupatorium perfoliatum* L. Thoroughwort, Boneset. L., 1.8—2.8 mm. W., .2—.5. C., dark grayish brown with irridescent spots. S., oblong, four-angled; contracted at the base into a rather long drawn out point. O., common in waste land. Native.

83. *Erigeron annuus* (L.) Pers. Daisy Fleabane, Sweet Scabious. L., .6—1. mm. W., .1—.4 mm. Color and shape as in the following species but slightly darker and with the hairs less evident. O., quite a bad weed. Introduced from Europe.

84. *Erigeron canadensis* L. Horseweed, Butterweed. L., .8—1.5 mm. W., .2—.6 mm. C., yellowish white. S., flattened; somewhat oval and broader at the apical end; covered with stiff white hairs. O., common in alfalfa and along hedge-rows. Native.

85. *Inula Helenium* L. Elecampane. L., 3.8—4.8 mm. W., .8—1.2 mm. C., light or dark brown. S., linear, four-angled with about twenty to thirty fine longitudinal lines; base of the pappus bristles quite persistent. O., common in rocky pastures and by roads. Introduced from Europe.

86. *Ambrosia trifida* L. Giant or Great Ragweed. L., 9—12 mm. W., 4—8 mm. C., dark brown to black. S., thick spindle-shaped or somewhat turbinate with five to seven very prominent ribs terminating in points slightly above the middle of the seed; beak 2—3 mm. long and quite thick at the base. O., common in low lands. Native.

87. *Ambrosia artemisiifolia* L. Ragweed, Roman Wormwood, Hogweed, Bitterweed. L., 2.4—4.8 mm. W., 1.1—1.5 mm. C., dark mottled brown. S., very thick spindle-shaped with from five to ten lateral ridges terminating in short beaks just above the middle; terminal beak about 1.5 mm. long. O., common in dry meadows and found in alfalfa, red clover and cereals. Native.

88. *Xanthium canadensis* Mill. Cocklebur, Clotbur. L., Fruit about 18 to 25 mm. long. W., about 10 mm. C., rusty brown. S., thick spindle-shaped terminating in two stout beaks

and covered with stout hooked spines; two seeds in each fruit; seeds are brown to black and flattened spindle-shaped. O., common in waste lands. Native.

89. *Xanthium spinosum* L. Cocklebur. Like the preceding species but about one-half the size and with much weaker spines.

90. *Heliopsis helianthoides* L. Sweet Ox-eye. L., 4.—6.4 mm. W., 1.8—2.6 mm. C., brown to straw-colored. S., oblong wedge-shaped usually very prominently four-angled; tapering at the base and abruptly cut off at the apex; with a very low collar or elevation at the apex. O., quite common. Native.

91. *Rudbeckia hirta* L. Black-eyed Susan, Yellow Daisy. L., 1.5—2. mm. W., .3—.5 mm. C., dark brown to black. S., somewhat four-angled; tapering from apical end to the base; apex concave; with twenty to thirty fine longitudinal lines composed of numerous small brick-shaped scales placed side by side. O., quite widely distributed and found chiefly in timothy seed. Native.

92. *Helianthus divaricatus* L. Wild Sunflower. L., 3.8—6.5 mm. W., 1.8—2.2 mm. C., brownish black, sometimes gray. S., obovate and slightly four-angled; pointed at one end. O., common in waste places, thickets, etc., also in alfalfa seeds. Native.

93. *Bidens frondosa* L. Beggar's ticks. L., 5—15 mm. W., 2—4 mm. C., dull brown blotched with black. S., diamond-shaped in cross section; much flattened; with two or sometimes three slightly diverging awns at the apical end. O., common in waste land. Native.

94. *Bidens cernua* L. Sticktight. L., 3.8—6.4 mm. W., 1.4—3. mm. C., dark greenish or grayish brown. S., somewhat wedge-shaped, four sided with a slight groove on each face and four awns at the apical or broader end. O., quite common. Introduced from Europe.

95. *Galinsoga parviflora* Cav. L., 1.2—1.6 mm. W., .5—.7 mm. C., dark gray or brown with numerous silvery hairs. S., somewhat pyramid-shaped with four sides; broadest towards the apex; surface covered with short (.2 mm.) upward pointing hairs and crowned at the apex with a fairly persistent row of white chaffy bristles. O., becoming rapidly abundant about Ithaca, New York; introduced near the Agricultural College about 1907. Native of tropical America.

96. *Achillea Millefolium* L. Yarrow, Milfoil, L., 1.8—2.5 mm. W., .7—1. mm. C., grayish flecked with darker spots. S., flattened obovoid, sometimes curved: apex abruptly contracted and bearing a tubercle; surface with numerous very fine longitudinal striations. O., rather common in grass seeds. Introduced from Europe.

97. *Anthemis Cotula* L. May-weed, Dog Fennel. L., 1.2—2. mm. W., .5—1.5 mm. C., light brown or dark straw-colored. or brown. S., obovoid with about ten ribs composed of tubercle-like projections; base tapering into a cone-shaped structure; with a small tubercle at the apical end. O., very common, especially in timothy, blue-grass and clover seeds. Introduced from Europe.

98. *Anthemis arvensis* L. Corn Chamomile. L., 1.4— 2.5 mm. W., .5—1.5 mm. C., light brown or dark straw-colored. S., somewhat four-angled or rounded in cross section; apex truncate and concave; base with a rounded knob; with about nine rounded ridges on the sides. C., quite common in clover seeds. Introduced from Europe.

99. *Chrysanthemum Leucanthemum* L. Ox-eye or White Daisy, White Weed. L., 1.5—2.4 mm. W., .6—1.1 mm. C., dark background with about ten heavy white ridges giving the whole a light appearance. S., obovate with ten longitudinal ridges slightly broader at apical end. O., frequent but not abundant in clover and small grass seeds. Introduced from Europe.

100. *Tussilago Farfara* L. Colt's Foot. L., 3.2—4 mm. W., .4—.6 mm. C., dark gray, appearing silvery because of the covering of gray hairs. S., narrowly spindle-shaped; more attenuate at the apex than at the base; with about six rows of long hairs pointing towards the apical end; circular in cross section. O., not a bad weed but very common in certain places. Introduced from Europe.

101. *Erechtites hieracifolia* (L.) Raf. Fireweed. L., 2.—3.1 mm. W., .3—.5 mm. C., dark brown with lighter markings. S., spindle-shaped with ten vertical light-colored ridges between which are minute appressed white hairs; expanded slightly at the extreme apex. C., common in certain regions. Native.

102. *Senecio vulgaris* L. Common Groundsel, Rag-wort, Squaw-weed. L., 2.4—3.6 mm. W., .2—.5 mm. C., light straw-colored with vertical rows of white ascending hairs. S., clavate

and abruptly truncate at the apex; base long attenuate; differs from *Tussilago Farfara* in being smaller and broader towards the apex rather than towards the base. O., quite common in waste places. Introduced from Europe.

103. *Arctium minus* Behr. Burdock. L., 4—6 mm. W., 1.8—2.8 mm. C., dark brown spotted or mottled with black; with fine longitudinal dark lines. S., straight or curved; somewhat oblong; tapering at the base; with a few narrow longitudinal ridges. O., not truly pernicious but common. Introduced from Europe.

104. *Cirsium lanceolatum* L. Hill. Common or Bull Thistle. L., 3.—4.2 mm. W., 1.2—2. mm. C., light straw-colored flecked with blackish markings. S., smooth, slightly flattened, obovate; apex set at an angle to the longitudinal axis, cup-shaped with incurving sides; base rather abruptly contracted. O., common in red clover, alfalfa and grass seeds. Naturalized from Europe.

105. *Cirsium arvense* L. Scop. Canada Thistle. L., 2.2—3.4 mm. W., .8—1.2 mm. C., rich golden brown. S., obovoid and slightly flattened, apex truncate and cup-shaped with incurving edges. O., found in clover seed. Naturalized from Europe.

106. *Centaurea Cyanus* L. Blue Bottle, Bachelor's Button, Corn Flower. L., 3.2—4.8 mm. W., 1.8—2.2 mm. C., shining white or yellowish gray, sometimes bluish white. S., flattened cylindrical except that the base is obliquely truncate; apex abruptly and squarely truncate with a tubercle in the middle; pappus bristles quite persistent. O., common in coarse clover and grass seeds. Appeared in Ithaca, New York, in 1885 and is growing more and more abundant each year. Introduced from Europe.

107. *Cichorium Intybus* L. Common Chicory, Blue Sailors. L., 2.5—3.5 mm. W., .8—1.2 mm. C., light yellowish brown, slightly mottled with black. S., irregularly truncate; four or five-angled with two to four faint longitudinal lines on each side; surmounted by a double row of scales or bristles. O., found in clover, alfalfa and grass. Introduced from Europe.

108. *Tragopogon porrifolius* L. Salsify. L., 10—18 mm. without pappus and 70-80 mm. with pappus. W., 1.8—2.3 mm. C., brownish gray flecked with small whitish scales. S., nearly cylindrical but quite spindle-shaped; tapering and curving at the

apex; ten ribbed, the ribs being composed of diverging scales; beak slender and from twenty to thirty mm. long. O., fairly common. Introduced from Europe.

109. *Tragopogon pratensis* L. L., 10—15 mm. without pappus; 12—25 with pappus. W., 1.4—2 mm. Color and shape, almost identical with *Tragopogon porrifolius*. O., common in rocky fields. Introduced from Europe.

110. *Taraxacum officinale* Weber. Common Dandelion. L., 3.—4.5 mm. without the style. W., .8—1.2 mm. C., straw-colored or dark reddish brown. S., oblanceolate with twelve to fourteen longitudinal ridges composed of barblike projections pointed toward the apical end, near which they are clustered; beak in two parts, one short and thick and the other two or three times the length of the achene. O., very common especially in grass seeds. Naturalized from Europe.

111. *Sonchus oleraceus* L. Common Sow Thistle. L., 2.8—3.1 mm. W., 1.—1.2 mm. C., straw-colored to reddish brown. S., flattened oval with nine to fourteen fine longitudinal ridges; both ends rather abruptly terminated; with transverse wrinkles. O., rather common in many farm seeds. Introduced from Europe.

112. *Sonchus asper* (L.) Hill. Spiny-leaved Sow Thistle. L., 2.2—3.2 mm. W., .8—1.2 mm. C., dull reddish brown. S., flattened oval sometimes with a slight wing; sometimes spindle-shaped; with three to five longitudinal ridges on each face. O., rather common. Introduced from Europe.

113. *Lactuca scariola* L. Prickly Lettuce. L., 3.—3.8 mm. W., .7—1 mm. C., dull brown and slightly mottled. S., spindle-shaped, slightly broader towards the apical end, with five to seven vertical ridges. O., spreading rapidly and becoming quite common. Introduced from Europe.

114. *Lactuca canadensis* L. Wild Lettuce or Horseweed. L., 3.3—4.8 mm. without the style. W., 1.5—2.2 mm. C., dusty black. S., flattened oval with three prominent ridges on each face; has the appearance of a winged seed; beak quite persistent. O., very common, and often troublesome. Native.

115. *Lactuca spicata* (Lam.) Hitchc. L., 3.5—5.2 mm. W., 1.—2.2 mm. C., dark brown. S., flat and irregularly oval with from ten to sixteen ridges. O., not particularly common. Native.

116. *Prenanthes alba* L. White Lettuce, Rattlesnake-root. L., 4.—6.2 mm. W., .8—1.4 mm. C., rich dark brown. S., linear oblong, contracted at the base but not at the apex; somewhat four-angled with seventeen to twenty long striations; pappus rusty brown. O., quite common. Native.

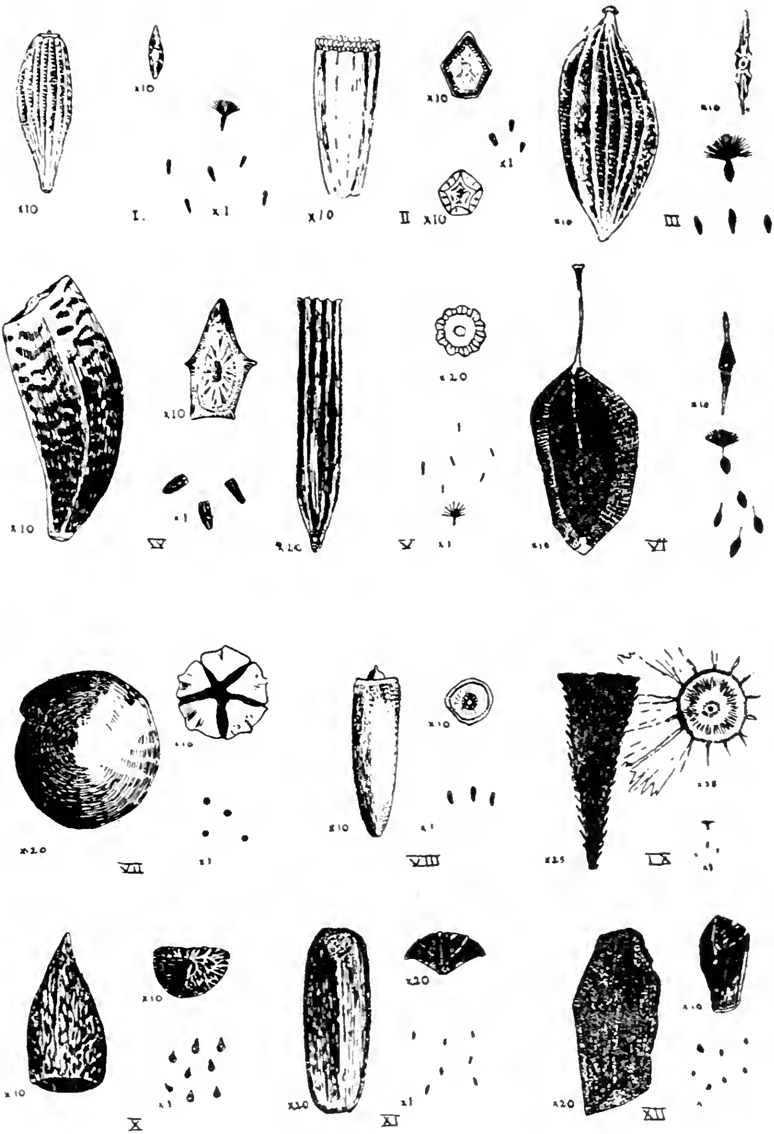
117. *Hieracium aurantiacum* L. Orange Hawkweed, Devil's Paint-brush. L., 1.8—2.4 mm. W., about .3 mm. C., dead black. S., fluted cylindrical with ten longitudinal ridges which dilate slightly at the apical end; with very fine hairs about 15 to 20 mm. arranged on the ridges and pointing towards the apical end. O., very common in grass seed. Naturalized from Europe.

118. *Hieracium scabrum.* Michx. L., 2.—2.8 mm. W., .2—.4 mm. Color, dead black. S., fluted cylindrical, expanded at the extreme apex and more attenuate at the base than *Hieracium aurantiacum;* hairs on the ridges also slightly more numerous. O., fairly common in pastures. Native.

KEY TO PLATE IX.

Seven-tenths size of original.

I. Sonchus oleraceus L.
II. Cichorium Intybus L.
III. Lactuca spicata (Lam.) Hitchc.
IV. Arctium minus Bernh.
V. Hieracium scabrum Michx.
VI. Lactuca canadensis L.
VII. Chenopodium hybridum L.
VIII. Cirsium arvense (L.) Scop.
IX. Galinsoga parviflora Cav.
X. Lithospermum arvense L.
XI. Verbena hastata L.
XII. Oenothera biennis L.


x10
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I.
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VII
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VIII
IX
x10
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X
x20
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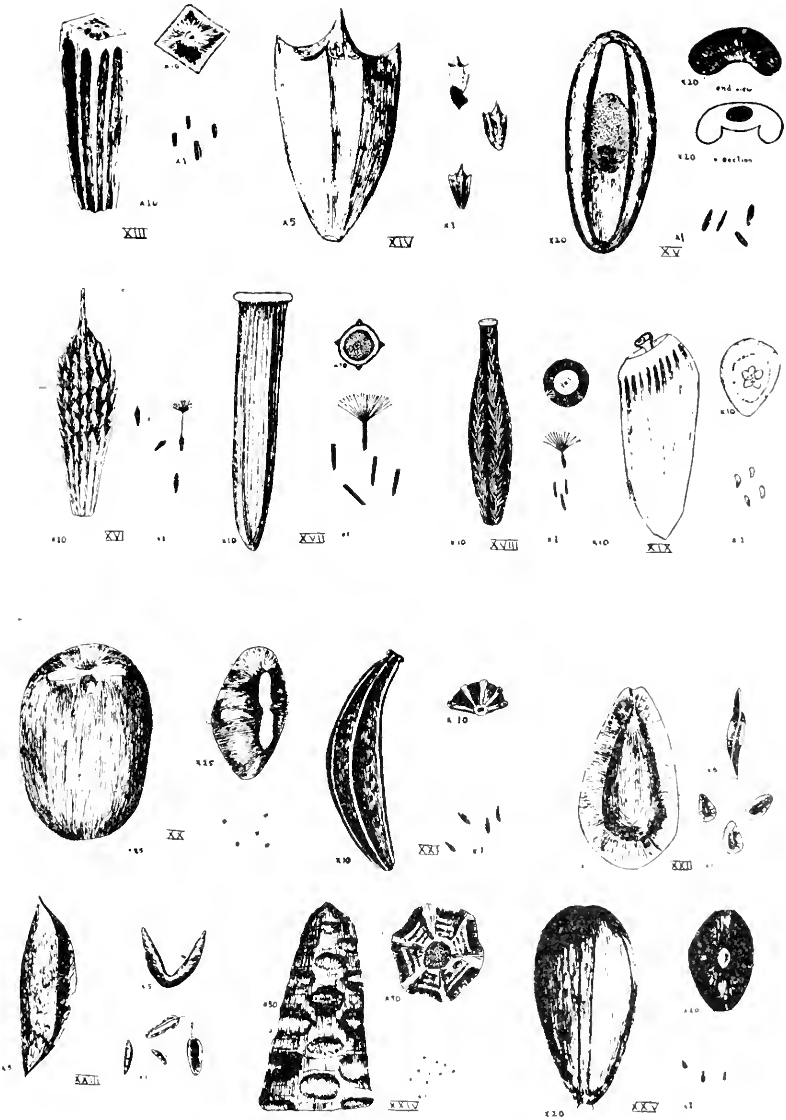
XI
x20
XII

KEY TO PLATE X.

Seven-tenths size of original.

XIII. Dipsacus sylvestris Huds.
XIV. Ambrosia trifida L.
XV. Plantago lanceolata L.
XVI. Taraxacum officinale Weber.
XVII. Prenanthes alba L.
XVIII. Tussilago Farfara L.
XIX. Cirsium lanceolatum (L.) Hill.
XX. Nepeta Cataria L.
XXI. Carum Carvi L.
XXII. Asclepias Syriaca L.
XXIII. Bromus secalinus L.
XXIV. Verbascum Thapsus L.
XXV. Prunella vulgaris L.

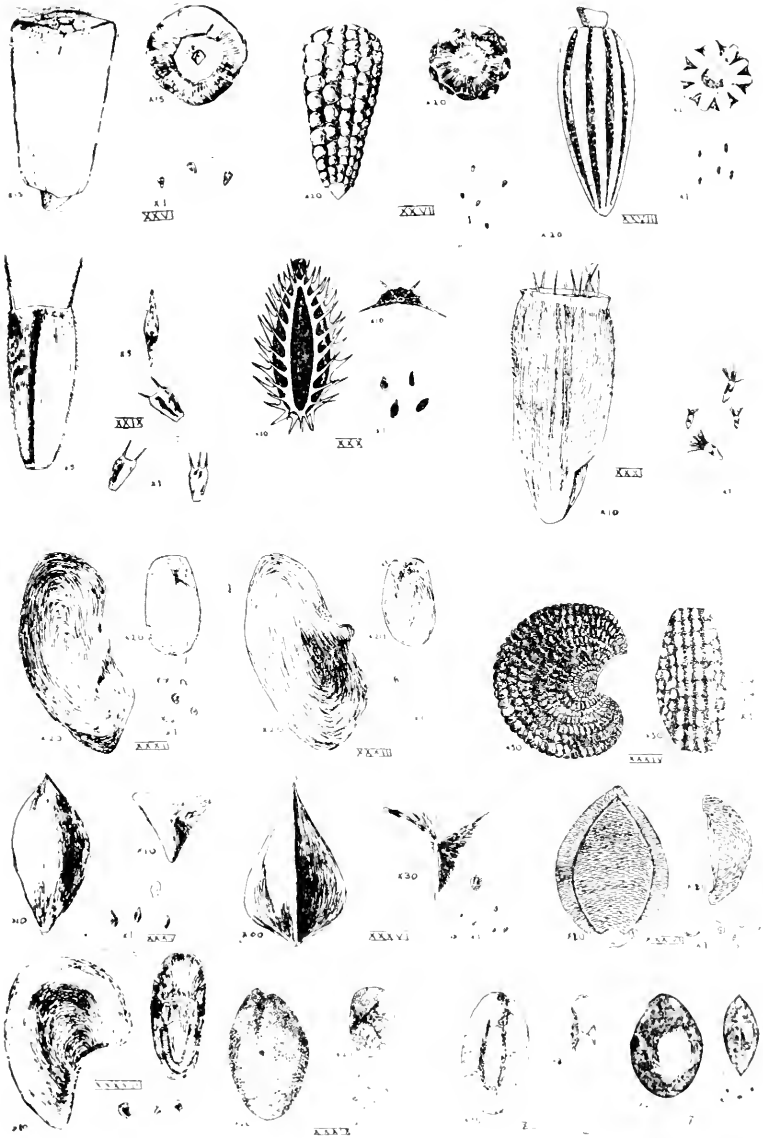
PLATE X


XIII
XIV
XV
end view
section
XVI
XVII
XVIII
XIX
XX
XXI
XXII
XXIII
XXIV
XXV

KEY TO PLATE XI.

Seven-tenths size of original.

XXVI.	Anthemis arvensis L.
XXVII.	Anthemis Cotula L.
XXVIII.	Chrysanthemum Leucanthemum L.
XXIX.	Bidens frondosa L.
XXX.	Daucus Carota L.
XXXI.	Centaurea Cyanus L.
XXXII.	Medicago sativa L.
XXXIII.	Medicago lupulina L.
XXXIV.	Stellaria media (L.) Cyrill.
XXXV.	Polygonum Convolvulus L.
XXXVI.	Rumex crispus L.
XXXVII.	Setaria glauca (L.) Beauv.
XXXVIII.	Abutilon Theophrasti Medic.
XXXIX.	Barbarea vulgaris R. Br.
XL.	Capsella Bursa-pastoris (L.) Medic.
XLI.	Amaranthus retroflexus L.


XXVI
XXVII
XXVIII
XXIX
XXX
XXXI
x30
XXXVI

KEY TO SEEDS.

I. 10 to 20 mm. long.
  1. With more than 1 appendage (figs. XXIX and XIV).
    2. Covered with hooked spines.
      3. 18 to 25 mm. long..............*Xanthium canadensis* Hill 88
      3. 10 to 13 mm. long..................*Xanthium spinosum* L. 89
    2. With appendages at apical end.
      3. With 2 to 4 nearly equal appendages (fig. XXIX).......
      ....*Bidens frondosa* L. 93
      3. With more than four unequal appendages or spines at apical end (fig. XIV) ....*Ambrosia trifida* L. 86
  1. Without more than 1 long appendage.
    2. 10 to 18 mm. long without pappus. Beak 1 to 10 mm. long
    ....*Tragopogon porrifolius* L. 108
    2. Beak short, about 4 mm. long...... *Tragopogon pratensis* L. 109

I. 9 to 10 mm. long.
  II. At least twice as long as broad.
    1. With 2 or 3 long equal terminal appendages (fig. XXIX)
    ....*Bidens frondosa* L. 93
  II. Not twice as long as broad.
    1. With numerous (4 to 8) unequal terminal straight appendages (fig. XIV)......................*Ambrosia trifida* L. 86
    1. With numerous (more than 8) terminal hooked prickles
    ....*Agrimonia striata* Michx. 45

I. 8 to 9 mm. long.
  II. At least twice as long as broad.
    1. With 2 or 3 terminal appendages (fig. XXIX)............
    ....*Bidens frondosa* L. 93
  II. Not twice as long as broad.
    1. With numerous terminal appendages.
      2. With 4 to 8 straight appendages (fig. XIV)...........
      ....*Ambrosia trifida* L. 86
      2. With more than 8 hooked appendages.................
      ....*Agrimonia striata* Michx. 45
    1. Without numerous appendages but with a wing...........
    ....*Asclepias syriaca* L. 62

I. 7 to 8 mm. long.
  II. At least twice as long as broad.
    1. With 2 to 4 long terminal appendages, flattish (fig. XXIX)
    ....*Bidens frondosa* L. 93
    1. Without terminal appendages, deeply grooved up one side (fig. XXIII)............................*Bromus secalinus* L. 11
  II. Not twice as long as broad.
    1. Triangular in cross section, shining black (figs. XXXV and XXXVI).....................*Polygonum scandens* Michx. 20

1. Not triangular in cross section or shining black.
 2. With numerous hooked terminal appendages...........
 ....*Agrimonia striata* Michx. 45
 2. Without terminal appendages but with a wing (fig. XXII)
 ....*Asclepias syriaca* L. 62

I. 6 to 7 mm. long.
 II. Spindle shaped with a deep groove up one side, twice as long as broad (fig. XXIII).................*Bromus secalinus* L. 11
 II. Not spindle shaped or with but one deep longitudinal groove.
 1. Triangular in cross section, shining black...............
 ....*Polygonum scandens* Michx. 20
 1. Not triangular in cross section.
 2. With terminal spines or prickles.
 3. With not more than 4 awns or prickles.
 4. With 4 awns, 4 angles, faces slightly concave......
 ....*Bidens cernua* L. 94
 4. With not more than 3 awns, usually 2, faces strongly 1-nerved (fig. XXIX)..............*Bidens frondosa* L.
 3. With more than 4 terminal prickles usually hooked
 ....*Agrimonia striata* Michx. 45
 2. Without terminal spines or prickles.
 3. Seeds winged (fig. XXII)..........*Asclepias syriaca* L. 62
 3. Seeds not winged.
 4. Uniform rusty brown, not over 1.4 mm. wide (fig. XVII)........................*Prenanthes alba* L. 116
 4. Not uniform, rusty red.
 5. Quite pronouncedly 4-faced, angles nearly equal..
 ....*Heliopsis helianthoides* L. Sweet 90
 5. Not pronouncedly 4-faced or equally angled, usually mottled in color.
 6. Usually with 1 or more longitudinal striations quite angular (fig. IV)....*Arctium minus* Berh. 103
 6. Without longitudinal striations, not angular....
 ....*Helianthus divaricatus* L. 92

I. 5 to 6 mm. long.
 II. At least twice as long as broad.
 1. With long terminal awns.
 2. With not more than 3, usually 2 straight awns (fig. XXIX)............................*Bidens frondosa* L. 93
 2. With 4 awns, 4-angled.................*Bidens cernua* L. 94
 1. Without long terminal awns.
 2. Less than 1 mm. thick, curved with from 10 to 16 longitudinal ridges, dark (fig. III).......................
 ....*Lactuca spicata* (Lam.) Hitchc. 115
 2. More than 1 mm. thick.
 3. Uniformly rusty red or gold-brown, less than 1.5 mm. broad, without a deep groove (fig. XVII)...........
 ....*Prenanthes alba* L. 116

3. Not uniformly rusty red or golden brown, more than 1.5 mm. broad.
    4. With a deep groove up one side...*Bromus secalinus* L. 11
    4. Without a deep groove up one side.
        5. Quite pronouncedly 4-faced and uniformly colored ....*Heliopsis helianthoides* L. Sweet. 90
        5. Not pronouncedly 4-faced, usually mottled in color.
            6. Usually with 1 or more longitudinal striations, quite angular (fig. IV)...*Arctium minus* Berh. 103
            6. Without longitudinal striations, not angular.... ....*Helianthus divaricatus* L. 92

II. Not twice as long as broad.
1. Triangular in cross section, shining black................ ....*Polygonum scandens* Michx. 20
1. Not triangular in cross section.
    2. With hooked terminal prickles (Bur)................. ....*Agrimonia striata* Michx. 45
    2. Without hooked terminal appendages.
        3. Almost globular white fruit.....*Rhus Toxicodendron* L. 53
        3. Not globular or white.
            4. Short kidney-shaped, flattened, brown, mottled with purple...............*Amphicarpa monoica* (L.) Ell. 52
            4. Somewhat fusiform, reddish with 4 or 5 distinct longitudinal ridges..............*Impatiens biflora* Walt. 54

I. 4 to 5 mm. long.

II. At least twice as long as broad.
1. Surface shining.
    2. Rich chestnut brown, oval......*Polygonum virginianum* L. 18
    2. Grayish white, obliquely truncate at base (fig. XXXI)... ....*Centaurea Cyanus* L. 106
1. Surface not shining.
    2. With numerous longitudinal notched ridges.
        3. Fruit broadest in middle, concavo-convex or plano-convex, oval ridges pronounced and notched entire length (fig. XXXV)......................*Daucus Carota* L. 61
        3. Fruit narrow, broadest toward apical end, oblanceolate, with 12-14 longitudinal ridges pronouncedly notched near apical end (fig. XVI) *Taraxacum officinale* Weber 110
    2. Without numerous longitudinal notched ridges.
        3. Surface smooth, not pronouncedly ridged.
            4. Seeds very light-colored, some faintly blotched with dark (fig. XIX).......*Cirsium lanceolatum* L. Hill. 104
            4. Seeds dark, usually mottled.
                5. Quite angular, mottled in transverse lines (fig. IV) ....*Arctium minus* Berh. 103
                5. Not angular, mottled longitudinally.............. ....*Helianthus divaricatus* L. 92

3. Surface with longitudinal striations.
 4. Fruit very thin but not narrow.
  5. Broader towards apex, winged, black with usually but one longitudinal ridge on each face (fig. VI) ....*Lactuca canadensis* L. 114
  5. Broadest toward base or near center, brown, with two or more longitudinal ridges (fig. III)...... ....*Lactuca spicata* Lam. Hitchc. 115
 4. Fruit not thin, nearly as thick as broad.
  5. More than 1.5 mm. broad.
   6. Quite pronouncedly 4-faced and uniform in color ....*Heliopsis helianthoides* L. Sweet. 90
   6. Not pronouncedly 4-faced and usually mottled in color.
    7. Usually with 1 or more longitudinal striations, angular and mottled transversely (fig. IV) ....*Arctium minus* Berh. 103
    7. Usually without longitudinal striations, not angular and if mottled, mottled longitudinally ....*Helianthus divaricatus* L. 92
  5. Less than 1.5 mm. broad.
   6. Quite pronouncedly curved, tapering at both ends with about 6 light longitudinal striations (fig. XXI) ....*Carum Carvi* L. 60
   6. Not pronouncedly curved or tapering at each end.
    7. With two deep grooves or three ridges on a side, comparatively short, quite 4-sided (fig. XIII)..............*Dipsacus sylvestris* Ruds. 80
    7. Without deep grooves or with more than 3 ridges on a side.
     8. Distinctly *reddish* brown, with 17-20 fine longitudinal striations (fig. XVII)........... ....*Prenanthes alba* L. 116
     8. Not *reddish* brown, with 20-30 fine longitudinal striations...........*Inula Helenium* L. 85

II. Not twice as long as broad.
 1. Triangular in cross section, shining black................. ....*Polygonum scandens* Michx. 20
 1. Not triangular in cross section.
  2. With numerous terminal appendages or spines.......... ....*Ambrosia artemisiifolia* L. 86
  2. Without numerous terminal appendages.
   3. Surface shining.
    4. Rich chestnut brown, oval..*Polygonum virginianum* L. 18
    4. Grayish white, obliquely truncate at base (fig. XXXI) ....*Centaurea Cyanus* L. 106
   3. Surface not shining.
    4. Fruit globular, white..........*Rhus Toxicodendron* L. 53
    4. Fruit not globular nor white.

5. Very thin, black, winged, with 1-2 fine longitudinal striations, broadest toward apex (fig. VI)........ ....*Lactuca canadensis* L. 114

5. Thicker, not winged.

6. Plano-convex or concavo-convex, broadest at middle, tapering at both ends almost equally (fig. XXX)........................*Daucus Carota* L. 61

6. Not tapering equally at both ends.

7. One side covered with prickles not arranged in lines, irregular in shape.................... ....*Lappula virginiana* (L.) Greene 66

Without spines.

8. With 4 to 5 longitudinal striations, tapering more acutely at apex, red................ ....*Impatiens biflora* Walt. 54

8. Without longitudinal striations, not red.

9. Plump, light brown with purplish blotches, no prominent notch at hilum............ ....*Amphicarpa monoica* (L.) Ell. 52

9. Slightly concave on each side with a pronounced notch at hilum, short kidney-shaped (fig. XXXVIII)................. ....*Abutilon Theophrasti* Medic. 55

I. 3 to 4 mm. long.

II. At least twice as long as broad.

1. With more than one persistent terminal appendage.

2. 1 to 4 awns at apex.

3. Awns ½ length of achene..............*Bidens cernua* L. 94

3. Awn less than ½ length of achene.......*Bidens connata* L.

2. With more than 4 terminal appendages.

3. With a double row of chaffy scales at apex (fig. II) ....*Cichorium Intybus* L. 107

3. With a pappus of capillary hairs at apex.

4. Seed light straw-colored and obliquely truncate at base, thick set (fig. XXXI)...*Centaurea Cyanus* L. 106

5. Dark brown, very slender and somewhat square in cross section...................*Inula Helenium* L. 85

3. Terminal appendages short and stiff.

4. Top-shaped with spines arranged in a ring around the top and with one in the center................ .... *Ambrosia artemisiifolia* L. 87

4. Somewhat spindle-shaped with 12-14 longitudinal ridges notched in short spines near apex (fig. XVI) ....*Taraxacum officinale* Weber 110

1. Without more than 1 persistent terminal appendage.

2. Surface shining, rich chestnut brown.................. ....*Polygonum virginianum* L. 18

2. Surface not shining.
  3. Surface smooth, not hairy or with longitudinal lines.
    4. More than 1.2 mm. wide, not reddish or tan.
      5. Light straw-colored (fig. XIX) ....*Cirsium lanceolatum* L. Hill. 104
      5. Dark-colored.............*Helianthus divaricatus* L. 92
    4. Less than 1.2 mm. wide, reddish (fig. VIII)....... ....*Cirsium arvense* L. Scop. 105
  3. Surface ridged or hairy, not smooth.
    4. Less than 1 mm. broad.
      5. Pronouncedly flattened.
        6. Very sharp attenuate at apex, dull brown...... ....*Lactuca scariola* L. 113
        6. Not sharply attenuate at apex.
          7. Distinctly reddish with fine longitudinal ridges ....*Sonchus oleraceus* L. 111
          7. Brown, with comparatively heavy longitudinal ridges (fig. XXX)..........*Daucus Carota* L. 61
      5. Not pronouncedly flattened.
        6. Square in cross section.
          7. Sharply pointed at base, very slender......... ....*Eupatorium purpureum* L. 81
          7. Not sharply pointed at base or slender...... ....*Dipsacus sylvestris* Huds. 80
        6. Not square in cross section.
          7. Very prominently 6- or 7-ridged, curved, usually greenish, plano- or concavo-convex (fig. XXX) ....*Daucus Carota* L. 61
          7. Not prominently 6- or 7-ridged or curved.
            8. Light brown, broadest toward apex.......... ....*Senecio vulgaris* L. 102
            8. Dark brown, broadest toward middle........ ....*Erechtites hieracifolia* (L.) Raf. 101
            8. Silvery or dark gray, broadest toward base (fig. XVIII)..........*Tussilago Farfara* L. 100
    4. More than 1 mm. broad.
      5. Surface not pronouncedly ridged.
        6. Very light colored, some faintly marked with dark (fig. XIX)....*Cirsium lanceolatum* L. Hill 104
        6. Not light colored.
          7. Quite angular, mottled in transverse lines (fig. IX)....................*Arctium minus* Berh. 103
          7. Not angular, mottled longitudinally........... ....*Helianthus divaricatus* L. 92
      5. Surface conspicuously ridged.
        6. Distinctly flattened.
          7. Black, winged with 1 to 2 ridges on each face (fig. VII)..............*Lactuca canadensis* L. 114

7. Dark brown with 10-16 ridges irregularly oval (fig. III).....*Lactuca spicata* (Lam.) Hitchc. 115
6. Not distinctly flattened.
7. Plano-convex or concavo-convex, ridges spiny, wide (fig. XXX)...........*Daucus Carota* L. 61
7. Square in cross section with 2 grooves on each face (fig. XIII).....*Dipsacus sylvestris* Huds. 80
7. Not square in cross section, very prominently 6- or 7-ridged, ridges not spiny, reddish (fig. XXI)........................*Carum Carvi* L. 60

II. Not twice as long as broad.
1. Triangular in cross section.
2. Black.
3. Shining black, over 3.5 mm......*Polygonum scandens* L. 20
3. Dull black, less than 3.5 mm. (fig. XXXV)...*Polygonum Convolvulus* L. 19
2. Not black.
3. Prominently transversely ridged with black or darker lines.......................*Setaria glauca* (L.) Beauv. 4
3. Surface not transversely striate, shining...................................*Echinochloa Crus-galli* L. Beauv. 3
1. Not triangular in cross section.
2. Black or nearly so.
3. Round and markedly shining...*Polygonum Persicaria* L. 17
3. Not round and not markedly shining.
4. Thin and wafer-like, usually winged.
5. Nearly circular without longitudinal striations.....................*Laportea canadensis* (L.) Gaud. 12
5. Oval with 1 to 2 longitudinal striations on each face (fig. VI).................*Lactuca canadensis* L. 114.
4. Not thin or wafer-like or winged.
5. One side covered with stiff prickles...............................*Lappula virginiana* (L.) 66
5. Not as above.
6. Acuminate at one end, not pronouncedly ridged ....*Helianthus divaricatus* L. 92
6. Not acuminate at one end.
7. Surface covered with gray hairs...............................*Malva moschata* L. 57
7. Surface not covered with hairs.
8. Nearly as thick as wide, surface with about 30 rows of short rounded projections, angular............*Agrostemma Githago* L. 31
8. Not nearly as thick as wide, surface with shallow pits somewhat kidney-shaped........................*Datura Stramonium* L. 73
2. Not black or nearly so.
3. Shining chestnut brown......*Polygonum virginianum* L. 18
3. Not shining chestnut brown.

4. Fruit white and almost globular.................... ....*Rhus Toxicodendron* L. 53
4. Not white or globular.
  5. Wafer-like usually with 2 short projections on the margin, often with a narrow wing.
    6. Style bent towards hilum, usually quite dark.... ....*Laportea canadensis* (L.) Gaud. 12
    6. Style straight or bent away from hilum......... ....*Ranunculus acris* L. 37
  5. Not wafer-like.
    6. Shining whitish, noticeably obliquely truncate at base, pappus quite persistent (fig. XXXI)..... ....*Centaurea Cyanus* L. 106
    6. Not shining white.
      7. With longitudinal striations noticeable to eye.
        8. With numerous terminal appendages, top-shaped ....*Ambrosia artemisiifolia* L. 87
        8. Without numerous terminal appendages.
          9. Plano-convex or concavo-convex, striations prominent and often spiny, greenish brown (fig. XXX).......*Daucus Carota* L. 61
          9. Not as above.
            10. Light colored.
              11. Plano-convex tapering almost equally at each end....................... ......*Echinochloa Crus-galli* L. Beauv. 3
              11. Tapering unequally at the ends, not plano-convex.
                12. Surface pitted, short and thick, hilum dark, apex long alternate, hard (fig. X).................... ....*Lithospermum arvense* L. 67
                12. Surface not pitted, not short and thick, apex not long alternate (fig. XIX).*Cirsium lanceolatum* L. Hill 104
            10. Dark colored.
              11. With four or five *marked* striations, not mottled, oval, reddish.......... ....*Impatiens biflora* Walt. 54
              11. Usually mottled without *marked* striations.
                12. Angular and mottled in transverse lines (fig. IV)..*Arctium minus* L. 103
                12. Not angular and if mottled, mottled longitudinally ....*Helianthus divaricatus* L. 92
      7. Without noticeable longitudinal striations.
        8. Plano-convex, not turbinate or kidney-shaped.

9. With fine *transverse* striations............ ....*Setaria glauca* L. Beauv. 4
9. Surface shining without transverse striations......*Echinochloa Crus-galli* L. Beauv. 3
8. Not plano-convex.
9. Somewhat turbinate, not at all kidney-shaped, hilum dark, surface light spotted with dark (fig. X)...................... ....*Lithospermum arvense* L. 67
9. Not at all turbinate, somewhat kidney-shaped.
10. Surface shallow-pitted, dark........... ....*Datura Stramonium* L. 73
10. Surface smooth, not pitted.
11. Usually over 3.2 mm. long, notch at hilum very deep (fig. XXXVIII).... ....*Abutilon Theophrasti* Medic. 55
11. Usually under 3.2 mm. long, notch at hilum not very deep............... ....*Malva moschata* L. 57

I. 2 to 3 mm. long.
II. At least twice as long as broad.
1. Appearing white or nearly so, streaked with dark gray.
2. Flattened ....*Achillea millefolium* L. 96
2. Not flattened (fig. XXVIII)............................ ....*Chrysanthemum Leucanthemum* L. 99

1. Not white or gray.
2. Black or nearly so.
3. Boat-shaped or allantoid in cross section, shining (fig. XV)......................*Plantago lanceolata* L. 79
3. Not boat-shaped or allantoid in cross section.
4. More than .6 mm. broad.
5. Shaped like a quarter of a cylinder, very regularly angled, crowned with short gray hairs........... ....*Leonurus Cardiaca* L. 72
5. Irregularly angled, surface not reticulated, angles distinct..................*Plantago Rugelii* Dcne. 78
5. Broad spindle-shaped, blunt at base, flattened on one side..........*Digitaria sanguinalis* (L.) Scop. 1
4. Less than .6 mm. broad.
5. Base drawn out into a long acute point, not jet black.
6. Over 2.8 mm. long, dark green-brown........... ....*Eupatorium purpureum* L. 81
6. Less than 2.8 mm. long, dark gray-brown........ ....*Eupatorium perfoliatum* L. 82
5. Base not drawn out into acute base, jet black.
6. Nearly square in cross section, 20 to 30 longitudinal lines................*Rudbeckia hirta* L. 91

6. Not nearly square in cross section with 10 longitudinal ridges................*Hieracium* sp. 117-118

2. Not black or nearly so.
 3. With numerous short terminal appendages and one long beak, turbinate............*Ambrosia artemisiifolia* L. 86
 3. With a double row of short persistent scales at terminal end (fig. II)...............*Cichorium Intybus* L. 107
 3. Without numerous terminal appendages.
  4. Surface markedly shining.
   5. Very dark brown, oval, a small whitish appendage near hilum, tapering at both ends (fig. XXV) ....*Prunella vulgaris* L. 71
   5. Light brown or tan, not tapering at both ends, a cuplike collar at apex (fig. VIII)............... ....*Cirsium arvense* L. Scop. 105
  4. Surface not markedly shining.
   5. Surface covered with about 10 longitudinal rows of tubercle-like projections (fig. XXVII)........... ....*Anthemis Cotula* L. 97
   5. Longitudinal lines if present not composed of tubercle-like projections.
    6. Thin and wafer-like, flattened.
     7. With a narrow wing, 3 to 5 regular ridges and broadest near middle...................... ....*Sonchus asper* L. Hill. 112
     7. Without a wing, broadest toward apex...... ....*Sonchus oleraceus* L. 111
    6. Not thin and wafer-like.
     7. Plano-convex or concavo-convex.
      8. Broad, with longitudinal rows on the surface usually composed of short bristles, not reddish.....................*Daucus Carota* L. 69
      8. Narrow, without many longitudinal rows of bristles.....*Digitaria sanguinalis* (L.) Scop. 1
     7. Not plano-convex or concavo-convex.
      8. Comparatively short and distinctly triangular in cross section.
       9. Equally 3-sided, angles not rounded...... ....*Rumex obtusifolius* L. 14
       9. Unequally 3-sided, angles slightly rounded ....*Polygonum aviculare* L. 16
      8. Not distinctly triangular in cross section.
       9. Light straw-colored, broad at apex, contracted at base, with about 9 longitudinal grooves (fig. XXVI)................ ....*Anthemis arvensis* L. 97
       9. Not light straw-colored or noticeably broader at the apex.

10. .5 mm. or less broad.
  11. Light brown, broadest toward the apex............*Senecio vulgaris* L. 102
  11. Dark brown, broadest toward the middle..*Erechtites hieracifolia* (L.) Raf. 101
10. Over .5 mm. broad.
  11. With pronounced lateral ridges.
    12. With more than 5 prominent ridges, not square in cross section, dark surface with lighter ridges (fig. XXI).............*Carum Carvi* L. 61
    12. With less than 5 prominent ridges, somewhat square in cross section, one face noticeably lighter and a light scar at hilum (fig. XI).......................*Verbena hastata* L. 69
  11. Without prominent lateral ridges............*Cirsium arvense* (L.) Scop. 105

II. Not twice as long as broad.
  1. Noticeably triangular or semi-circular in cross section.
    2. Semi-circular in cross section.
      3. Surface smooth.......*Echinochloa Crus-galli* (L.) Beauv. 3
      3. Surface not smooth.
        4. With lateral striations, usually over 2.5 mm. long (fig. XXXVII)................*Setaria glauca* (L.) Beauv. 4
        4. With lateral and longitudinal striations, usually 2.5 mm. long ....*Setaria viridis* (L.) Beauv. 5
    2. Not semi-circular in cross section but noticeably triangular.
      3. Dull black, over 2.5 mm. long..*Polygonum Convolvulus* L. 19
      3. Brown or tan, usually under 2.5 mm. long.
        4. Shining, abruptly attenuate at end, angles acute.
          5. Sides and angles concave and dipping just back of apex (fig. XXXVI).............*Rumex crispus* L. 13
          5. Sides and angles straight, apex more acuminate...........................*Rumex obtusifolius* L. 14
        4. Not shining, angles somewhat rounded, unequally 3-sided ....*Polygonum aviculare* L. 16
  1. Not noticeably triangular in cross section.
    2. Thin and wafer-like.
      3. White or light gray, obovoid....*Achillea millefolium* L. 96
      3. Not white or light gray.
        4. Black or blackish.
          5. Shining, almost round.....*Polygonum Persicaria* L. 17
          5. Not shining.
            6. With a broad wing all around periphery...............................*Linaria vulgaris* Hill. 76

6. With a narrow wing and two projections, the style bent towards hilum.................... ....*Laportea canadensis* L. Gaud. 12
4. Not black or blackish.
5. Margin rounded..........*Polygonum Persicaria* L. 17
5. Margin acute..................*Ranunculus acris* L. 37
2. Not thin and wafer-like.
3. Surface shining.
4. Flattened.
5. Round..................*Chenopodium hybridum* L. 21
5. Not round.
6. Black, broadly spindle formed................. ....*Polygonum Persicaria* L. 17
6. Not black, shield shaped....*Trifolium pratense* L. 46
4. Not flattened.
5. With a small white appendage at base (fig. XXV) ....*Prunella vulgaris* L. 71
5. Dark disk at base, turbinate..*Lithospermum arvense* 67
3. Surface not shining.
4. Diameter from end to end nearly uniform, somewhat 4-angled.
5. Dark brown and comparatively thick............. ....*Verbena urticaefolium* L. 68
5. Light brown and comparatively slender........... ....*Verbena hastata* L. 69
4. Diameter not uniform from end to end.
5. Black or nearly so.
6. Covered with bristling gray hairs (fruit)...... ....*Malva moschata* L. 57
6. Not covered with gray hairs.
7. More than 2.5 mm. long..*Agrostemma Githago* L. 31
7. Less than 2.5 mm. long..................... ....*Saponaria officinalis* L. 34
5. Not black or nearly so.
6. Pointed at least at one end.
7. Plano-convex or concavo-convex with longitudinal striations, oval (fig. XXX)............ ....*Daucus Carota* L. 61
7. Not plano-convex or concavo-convex.
8. Distinctly red-brown.
9. Coat closely fitting, irregularly or regularly triangular in cross section, reddish brown (fig. XXX)........*Daucus Carota* L. 61
9. Coat loosely fitting, angles slightly winged ....*Oenothera biennis* L. 59
8. Not red-brown.
9. Broadest at apex, light straw-colored with about 9 longitudinal lines (fig. XXVI).. ....*Anthemis arvensis* L. 98

9. Broadest toward base, turbinate, base very dark (fig. X)....*Lithospermum arvense* L. 67

6. Not pointed at either end.

7. With longitudinal striations or sharp angles.

8. Dark brick-red..........*Oenothera biennis* L. 59

8. Not dark brick-red.

9. Plano-convex or concavo-convex, greenish brown (fig. XXX).......*Daucus Carota* L. 61

9. Not plano-convex or concavo-convex, light straw-colored, blunt at the ends (fig. XXVI).............*Anthemis arvensis* L. 98

7. Without longitudinal striations.

8. Flattened or concave on two sides.

9. Covered with short hairs (fruit)..........
......................*Malva moschata* L. 57

9. Not covered with short hairs.

10. With a narrow wing, almost round, thin at edges.......*Ranunculus abortivus* L. 36

10. Without a narrow wing, thick at one edge, thinner at the other.

11. No angles, edges rounded, faces concave with outer coat on..............
..................*Malva moschata* L. 57

11. Faces plane with outer coat on, darker than next preceding..*Malva rotundifolia* L. 56

8. Not flattened or concave, faces slightly convex.

9. With a short distinct elevation near scar reaching beyond the normal outline of the seed (fig. XXXIII)...*Medicago lupulina* L. 51

9. Without a short distinct elevation at scar extending beyond normal outline of seed.

10. Kidney shaped or angular usually with deep concavity near scar (fig. XXXII)
.....................*Medicago sativa* L. 50

10. Almost uniformly oval.

11. Usually over 2 mm. long, notch near one end..........*Melilotus alba* Desr. 49

11. Usually under 2 mm. long, notch near the center of one side.............
................*Trifolium pratense* L. 46

I. 1 to 2 mm. long.

II. At least twice as long as broad.

1. Black or nearly so.

2. Rounded alike at both ends, bisymmetric when cut transversely; surface appearing granular but composed of rectangular markings ....*Hypericum perforatum* L. 58

2. Not rounded at both ends or bisymmetric when cut transversely.

3. Quite pronouncedly square in cross section.

4. Angles acute, base contracted to a sharp point........ ....*Eupatorium perfoliatum* L. 82
4. Angles slightly rounded, apex slightly rounded, base not contracted to a sharp point..*Rudbeckia hirta* L. 91
4. Angles rounded, seed like a four sided pyramid with short white hairs, not over 1.6 mm. long (fig. IX) ....*Galinsoga parviflora* Cav. 95
3. Not pronouncedly square in cross section.
4. Fluted cylindrical in shape, usually over 1.8 mm. long............................*Hieracium* sp. 117-118
5. Quite attenuate at base..*Hieracium scabrum* Michx. 118
5. Abruptly contracted at base...................... ....*Hieracium aurantiacum* L. 117
4. Not fluted cylindrical in shape.
5. Over 1.1 mm. long.
6. Pyramid or cone-shaped with numerous short white hairs, pappus of chaffy bristles when present (fig. IX).....*Galinsoga parviflora* Cav. 95
6. Irregularly angled, surface not covered with hairs, no pappus, not reticulate, granular........... ....*Plantago Rugelii* Dcne 78
5. Under 1.1 mm. long..*Glyceria nervata* (Willd.) Trin. 10
1. Not black or nearly so.
2. Nearly triangular in cross section.
3. With more than 3 prominent longitudinal striations (fig. XXX)........................*Daucus Carota* L. 61
3. With but 3 prominent longitudinal striations.
4. Rich dark reddish, comparatively short.
5. Surface shining, angles distinct, sides nearly equal ....*Rumex obtusifolius* L. 14
5. Surface dull, angles sometimes rounded, especially toward base..............*Polygonum aviculare* L. 16
4. Light brown, comparatively long, a shallow groove on one side, angles often hairy..........*Poa pratensis* L. 9
2. Not triangular in cross section.
3. Appearing white or light gray.
4. Thin and wafer-like, white with darker markings.. ....*Achillea Millefolium* L. 96
4. Background dark with 10 heavy white longitudinal ridges, not wafer-like (fig. XXVIII)............... ....*Chrysanthemum Leucanthemum* L. 99
3. Not appearing white or light gray.
4. Thin, wafer-like, cream-colored.
5. With a slight margin around the edge, translucent, "usually under .9 mm. long" B., sometimes slightly over 1 mm...........*Erigeron annuus* (L.) Pers. 83
5. Without noticeable margin with noticeable hairs, "usually over .9 mm. long." Beal................ ....*Erigeron canadensis* L. 84

4. Not thin, wafer-like and cream-colored.
 5. Angular or angles distinct.
  6. Very light straw-colored with about 9 rounded longitudinal ridges (fig. XXVIII)..*Anthemis arvensis* L. 98
  6. Not light straw-colored.
   7. Distinctly square in cross section, very dark brown to black.
    8. Angles acute, base drawn into an attenuate point almost uniform in diameter except at base, pappus capillary, over 1.8 mm. long.................. *Eupatorium perfoliatum* L. 82
    8. Angles not acute, pappus of chaffy bristles, surface hairy, not uniform in diameter, tetrahedonal, under 1.8 mm. long (fig. IX)....................*Galinsoga parviflora* Cav. 95
   7. Not distinctly square in cross section.
    8. Plano-convex or concavo-convex in cross section.
     9. With 2 to 5 rows of frail spines on convex surface, longitudinal ends not attenuate, lines pronounced (fig. XXX)...................................*Daucus Carota* L. 61
     9. Without longitudinal rows as above, ends attenuate........*Digitaria sanguinale* Scop. 1
    8. Not plano-convex or concavo-convex with longitudinal striations.
     9. Cone shaped, with numerous gray hairs and pappus of chaffy bristles (fig. IX)................*Galinsoga parviflora* Cav. 95
     9. Not cone shaped or hairy.
      10. With longitudinal ridges or angles.
       11. Comparatively thick set, dark, see description....*Verbena urticaefolium* L. 68
       11. Comparatively slender and light (fig. XI)...............*Verbena hastata* L. 69
      10. Without marked *longitudinal* striations.
       11. Surface finely reticulate.................................*Plantago major* L. 77
       11. Surface granular, not reticulate.....................*Plantago Rugelii* Dcne. 78
 5. Not angular.
  6. Surface shining.
   7. Not at all uniform in diameter.
    8. Uniform in shape, one end pointed, usually with a whitish triangular appendage (fig. XXV).................*Prunella vulgaris* L. 71
    8. Not uniform in shape.

9. With a slight groove down each side, variously colored. *Sisymbrium officinale* Scop. 41
9. Without a groove on each side, surface finely reticulate........ *Plantago major* L. 77

7. Quite uniform in diameter.
8. With a slight groove down each side, variously colored.. *Sisymbrium officinale* Scop. 41
8. Without a groove on each side.
9. Almost circular in cross section, surface with rectangular markings.............................. *Hypericum perforatum* L. 58
9. Not circular in cross section, surface finely reticulate............. *Plantago major* L. 77

6. Surface not shining.
7. Compressed.
8. With a groove on each side.
9. Groove indicated by a loop or double line, not over 1.3 mm. long (fig. XL)................. *Capsella Bursa-pastoris* L. Medic. 39
9. Groove indicated by a single line.
10. Groove running out on to one end............. *Sisymbrium officinale* L. Scop. 41
10. Groove ending on the face of the seed, broader........ *Lepidium ruderale* L. 38

8. Without a groove on each side.
9. Surface finely reticulate.. *Plantago major* L. 77
9. Surface not reticulate.
10. Light straw-colored and spindle-shaped.
11. Scar on one side extending about one-half length of seed, seed not under 1.6 mm. long.... *Digitaria sanguinale* Scop. 1
11. Scar on one side short, not more than one-fourth length of seed, seed not over 1.2 mm. long .... *Agrostis alba* Schrad. 7

10. Not light straw-colored or spindle-shaped.
11. Not at all kidney-shaped, usually dark brown to black, *Plantago Rugelii* Dcne. 78
11. Usually kidney-shaped and usually not dark brown to black.
12. With a short distinct elevation near scar reaching beyond the normal outline of the seed (fig. XXXIII) .... *Medicago lupulina* L. 51

12. Without a short distinct elevation at scar extending beyond normal outline of seed.

13. Kidney-shaped or slightly angular, usually with a deep concavity near scar (fig. XXXII).........
...............*Medicago sativa* L. 50

13. Almost uniformly oval.

14. Usually over 2 mm. long, notch near one end.................
............*Melilotus alba* Desr. 49

14. Usually under 2 mm. long, notch near center of one side.......
.........*Trifolium pratense* L. 46

7. Not compressed.

8. With about 10 ribs composed of tubercle-like projections, broader at apex, dark (fig. XXVII)................*Anthemis Cotula* L. 97

8. Without ribs composed of tubercle-like projections.

9. With about 9 prominent rounded longitudinal ridges, light straw-colored (fig. XXVIII)...........*Anthemis arvensis* L. 98

9. Without 9 prominent rounded ridges.

10. Surface finely marked throughout.

11. Diameter nearly uniform, ends rounded with rectangular markings.......
............*Hypericum perforatum* L. 58

11. Diameter not uniform, reticulated longitudinally, irregularly shaped...
...................*Plantago major* L. 77

10. Surface not finely marked throughout.

11. Dark brown.

12. Cone- or tetrahedral-shaped, usually with white hairs, broadest at one end (fig. IX)....................
..........*Galinsoga parviflora* Cav. 95

12. Irregularly shaped, no hairs, not broadest at one end...............
.... *Plantago Rugelii* Dcne. 78

11. Light straw-colored, spindle-shaped.

12. Scar on one side extending at least one-third length of seed, seed usually over 1.7 mm. long............
..........*Digitaria sanguinale* Scop. 1

12. Scar on one side extending only one-fourth length of seed, seed under 1.4 mm. long...............
...............*Agrostis alba* Schrad. 7

II. Not twice as long as broad.

1. Distinctly triangular in cross section.

2. With more than 3 longitudinal ridges, greenish in color (fig. XXX) .... *Daucus Carota* L. 61
2. With 3 or less longitudinal ridges.
3. Equilateral or very nearly so.
4. Without pointed ends, angles sometimes indistinct, never over 2 mm. long .... *Rumex Acetosella* L. 15
4. With pointed ends, angles very distinct, apical end sharp pointed, basal end blunt pointed, shining.
5. Rarely under 2 mm. long, less shining than the following species, apex more acuminate .... *Rumex obtusifolius* L. 14
5. Usually about 2 mm. long, shiny, apex not attenuate, angles dip slightly just back of apex (fig. XXXVI) .... *Rumex crispus* L. 13
3. Not equilateral.
4. Light straw-colored.
5. Over 1.5 mm. long .... *Setaria viridis* K. Braw. 4
5. Less than 1.5 mm. long .... *Agrostis alba* L. 7
4. Not light straw-colored.
5. Seed coat loosely fitting, irregularly shaped, brick red (fig. XII) .... *Oenothera biennis* L. 59
5. Seed coat tightly fitting.
6. Surface granular, usually black .... *Plantago Rugelii* Dcne. 78
6. Surface finely striate.
7. Usually over 1.8 mm. long with a remnant of calyx at one end, other end quite acuminate, striations quite straight .... *Polygonum aviculare* L. 16
7. Usually under 1.8 mm. long, irregularly shaped, striations wavy, variously colored .... *Plantago major* L. 77

1. Not triangular in cross section.
2. Black or nearly so.
3. Round with a wing.
4. Wing very broad, seed very thin .... *Linaria vulgaris* Hill. 76
4. Wing narrow, seed thick .... *Spergula arvensis* L. 27
3. Without a wing.
4. Shining markedly.
5. Slightly pointed at opposite ends, fairly thick edges rounded .... *Polygonum Persicaria* L. 17
5. Not pointed at opposite ends.
6. Calyx persistent, when rubbed off seeds slightly flattened on both faces.
7. One side flattened more than the other, margin not always rounded, slight curved groove on one side .... *Chenopodium album* L. 22

7. Equally flattened or convex, margin rounded, no groove but a slight notch present (fig. VII) .... *Chenopodium hybridum* L. 21

6. Calyx not markedly persistent, seeds strongly convex on both faces.

7. Seeds almost perfectly round in outline, rarely over 1.2 mm. long.... *Amaranthus graecizans* L. 26

7. Seeds not perfectly round in outline, broadly ovate.

8. Angle at margin very marked, usually larger than next following species................ .... *Amaranthus hybridus* L. 25

8. Angle at margin indistinct, usually smaller (fig. XLI)........ *Amaranthus retroflexus* L. 24

4. Not shining, dull.

5. Not at all round, angles quite distinct.

7. Surface with fine reticulations.. *Plantago major* L. 77

6. Surface granular, not reticulate................. .... *Plantago Rugelii* Dcne. 78

5. Round or nearly so.

6. Surface covered with concentric rows of small tubercle-like projections giving a granular appearance, somewhat kidney-shaped............ .... *Saponaria officinalis* L. 34

6. Surface quite smooth.

7. Broadly notched at one side, not lens-shaped.. .... *Trifolium hybridum* L. 48

7. Notch slight, somewhat lens-shape.

8. With calyx present, lines of calyx run transversely entirely across the seed; with calyx off a "groove runs from the side to the notch".................. *Atriplex patula* L. 23

8. With calyx present, lines of the calyx run radially; with calyx off, a groove runs from notch to center of the face of the seed.... .... *Chenopodium album* L. 22

2. Not black or nearly so.

3. Shining surface.

5. Over 1.8 mm. long.

5. Pronouncedly compressed, broad oval or kidney-shaped.

6. Black .... *Polygonum Persicaria* L. 17

6. Not black................. *Trifolium pratense* L. 46

5. Not pronouncedly compressed.

6. Usually with a whitish appendage at base, not flattened on one side (fig. XXV).............. .... *Prunella vulgaris* L. 71

6. Flattened slightly on one side, without appendage .... *Setaria viridis* L. Beauv. 5

4. Under 1.8 mm. long.
 5. Light straw-colored, slightly flattened on one side, see description .... *Panicum capillare* L. 2
 5. Not light straw-colored.
  6. With a pronounced groove running up one side and onto the end.... *Sisymbrium officinale* Scop. 41
  6. Without a groove.
   7. Surface finely reticulate...... *Plantago major* L. 77
   7. Surface finely pitted...... *Barbarea vulgaris* R. Br.
3. Surface dull.
 4. Surface covered with pits or tubercle-like projections easily visible with hand lens.
  6. Shallow pitted or granular.
   7. Granular, usually flesh-colored, light.......... .... *Cuscuta arvensis* Beyrich 65
   7 Distinctly pitted, not flesh-colored.
    8. Irregularly flattened; convex at scar with a slight concavity on either side near scar (fig. XXXIX) .... *Barbarea vulgaris* R. Br. 42
    8. Not flattened markedly, scar not as noticeably convex, duller in color than the next preceding .... *Brassica nigra* L. Koch. 40
  6. Deeply pitted in longitudinal rows (fig. XXIV) .. *Verbascum Thapsus* 74 or *Verbascum Blattaria* 75
 5. Surface with tubercle-like elevations.
  6. Round to short kidney-shape.
   7. Distinctly red in color, usually not over 1.2 mm. in diameter, somewhat angular with about 5 rows of tubercles on each face (fig. XXXIV) .... *Stellaria media* L. Cyril. 29
   7. Not usually distinctly red in color, over 1.2 mm. in diameter.
    8. Background of seed brown, rarely reddish, not angular, short kidney-shaped............. .... *Silene noctiflora* L. 33
    8. Background of seed distinctly black or dark gray, somewhat more angular and larger than next preceding...... *Lychnis alba* Mill. 32
  6. Seeds not at all kidney-shaped, ridges not distinctly tubercled (fig. XXIV)................. *Verbascum Thapsus* L. 74 or *Verbascum Blattaria* L. 75
 4. Surface not pitted or tubercled.
  5. Wafer-like, thin especially at the edges.
   6. With longitudinal lines (fig. XXX)............ .... *Daucus Carota* L. 61
   6. Without longitudinal lines.
    7. Without projections on the margin, usually narrowly winged with a groove on each side .... *Arabis laevigata* Muhl. Poir. 43

7. Usually winged and with at least 1 short curved projection on the margin, without grooves on the sides............*Ranunculus abortivus* L. 36

5. Not wafer-like or thin at the edges.

6. With pronounced lateral ridges.

7. Distinctly reddish or dark brown in color.

8. Regularly 3-angled, not always equilateral.. ....*Polygonum aviculare* L. 16

8. Not regularly 3-angled.

9. Oval, flattened with 2 marked longitudinal striations (see description).............. ....*Setaria viridis* L. Beauv. 5

9. Irregularly shaped, angles distinct (fig. XII) ....*Oenothera biennis* L. 59

7. Not distinctly reddish in color.

8. With about 9 distinct rounded longitudinal ridges, broadest at apex, light straw-colored usually (fig. XXVI)....*Anthemis arvensis* L. 98

8. Not broadest at apex and with 9 distinct rounded longitudinal ridges.

9. Irregularly shaped, black when fully ripe.

10. Surface finely reticulate............... ....*Plantago major* L. 77

10. Surface not reticulate, granular........ ....*Plantago Rugelii* Dcne. 78

9. Regularly shaped.

10. With more than 2 longitudinal ridges (fig. XXX)............*Daucus Carota* L. 61

10. With not more than 2 longitudinal lines.

11. More than 1.5 mm. long............ ....*Setaria viridis* L. Beauv. 5

11. Less than 1.5 mm. long.............. ....*Agrostis alba* L. 7

6. Without pronounced lateral ridges.

7. With two small oval white scars placed end to end near one end of the seed (fig. XX).. ....*Nepeta Cataria* L. 70

7. Without scars as above.

8. Ellipsoidal in cross section and almost circular in greatest outline, usually with a narrow lighter colored wing, angle at edge distinct................*Spergula arvensis* L. 27

8. Not as above.

9. Markedly angled and irregular in shape.

10. With a distinct groove on the faces of the seed, quite strongly flattened.

11. Groove extending entire length of seed .....*Sisymbrium officinale* (L.) Scop. 41

11. Groove not extending entire length of seed, quite flattened, pointed at one end............*Lepidium ruderale* L. 38

10. Without a distinct groove on the faces.

11. Seed coat loosely fitting or wrinkled, brick red, angles very distinct and acute (fig. XII)..*Oenothera biennis* L. 59

11. Seed coat not noticeably wrinkled, angles more rounded.

12. Not black when ripe, usually flesh-colored and granular.......................*Cuscuta arvensis* Beyrich 65

12. Black when fully ripe.

13. Surface reticulated.............................*Plantago major* L. 77

13. Surface not reticulated...................*Plantago Rugelii* Dcne. 78

9. Not markedly angled, quite regular in shape.

10. Almost round, both faces concave, a slight notch at one edge, the opposite edge thicker...............*Malva* sp. 56-57

11. Dark reddish brown usually under 2 mm. in diameter.................................*Malva rotundifolia* L. 56

11. Light grayish in color, usually over 2 mm. in diameter...................................*Malva moschata* L. 57

10. Not round, with both faces concave as above.

11. With a distinct longitudinal groove starting at the narrow end of the seed and extending at least one-half length of seed.

12. Surface finely dotted or pitted, distinctly gray-brown, somewhat shiny; inserted here as a check (fig. XXXIX)............................*Barbarea vulgaris* R. Br. 42

12. Surface not finely dotted or pitted.

13. Groove extending entire length of the seed and running on the end, broader ....*Sisymbrium officinale* Scop. 41

13. Groove not extending entire length of seed.

14. Groove double or looped, under 1.2 mm. long (fig. XL)....... *Capsella Bursa-pastoris* A. Medic. 39

14 Groove single extending one-half to two-thirds length of seed, flattened and over 1.3 mm. long..*Lepidium ruderale* L. 38

11. Without a distinct longitudinal groove.

12. At least one end sharply pointed, oily in appearance, usually with an accompanying scale.

13. Usually over 1.2 mm. long, pointed each end......*Phleum pratense* L. 6

13. Usually under 1.2 mm. long, pointed at one end, scar less than one-fourth length of seed ....*Agrostis alba* Schrad. 7

12. Ends not sharp pointed, appearance not oily, never with accompanying scale.

13. Surface very finely pitted.

14. Light flesh-colored, often with 2-3 adjacent flattened areas... ......*Cuscuta arvensis* Beyrich 65

14. Not light flesh-colored or as above.

15. Irregularly flattened, somewhat shiny (fig. XXXIX) ....*Barbarea vulgaris* R. Br. 42

15. Not markedly flattened, duller than the next preceding.... .....*Brassica nigra* L. Koch. 40

13. Surface not finely pitted.

14. Surface granular.

15. Without notch near the scar, dark colored............... .....*Cuscuta Gronovii* Willd. 63

15. Light flesh-colored, often with flattened areas clearly marked by angles.......... ....*Cuscuta arvensis* Beyrich 65

14. Surface not granular, usually with a notch near the scar.

15. With a short distinct elevation near the scar reaching beyond the normal outline of the seed, scar on the side nearer one end, usually over 1.5 mm. long (fig. XXXIII) ....*Medicago lupulina* L. 51

17 Without a short distinct elevation near the scar reaching beyond the normal outline of the seed

18 Under 1.7 mm. long, with scar and notch at one end, scar at the deepest part of notch and small

19 Dark green to black
Trifolium hybridum L.

19 Light yellowish to yellow-brown
Trifolium repens L.

18 Over 1.7 mm. long, notch not usually at one end

19 Kidney-shaped or angular, usually with a deep concavity near the scar, fig. XXXVII
Medicago sativa L.

19 Almost uniformly oval

20 Usually over 2 mm. long, notch toward one end, rarely in this section of the key
Melilotus alba Desr.

20 Usually under 2 mm. long, notch near the center of one side
Trifolium pratense L.

I 1 to 2 mm. long

II Surface shining

III With numerous curved forked ridges or wrinkles
.... *Portulaca oleracea* L.

III Without numerous curved forked ridges or wrinkles

1 Surface pitted, with fine rectangular markings, or with rows of minute rounded elevations

2 Surface minutely pitted, oval, brown, scar at narrowest end, fig. XXXIX .... *Barbarea vulgaris* R. Br.

2 Surface with concentric rows of fine tubercular projections, black, round or short kidney-shaped
[illegible]

2 Surface with fine rectangular markings, cylindrical, dark brown to black .... *Hypericum perforatum* L.

1 Surface not pitted, with fine markings or rows of minute rounded elevations

2 Possessing a longitudinal groove running more than one-half length of seed

3 Not black

4. Long oval or irregular in shape with a groove running the entire length of the seed and onto the end..............*Sisymbrium officinale* Scop. 41
4. With a double or looped groove..................
.................*Capsella Bursa-pastoris* A. Medic. 39
3. Black or with slight brown cast at apex, pointed at both ends................*Glyceria nervata* Trin. 10
2. Without a groove running more than one-half length of seed.
3. Thickest in the middle coming to a more or less acute angle at the edge, notch at scar very shallow.
4. Ovate, angle at edge more rounded................
........................*Amaranthus retroflexus* L. 24
4. Round, angle at edge distinct, slightly smaller than next preceding..........*Amaranthus graecizans* L. 26
3. Angles at edges rounded, notch at scar quite marked.
4. Green to black...............*Trifolium hybridum* L. 48
4. Yellow to light brown..........*Trifolium repens* L. 47

II. Not shining.
III. With distinct forked curved wrinkles or ridges, light colored......................*Potentilla monspeliensis* L. 44
III. Without distinct forked curved wrinkles or ridges.
1. Surface with a longitudinal groove starting at one end, not pitted.
2. Groove looped or double, not running the entire length of the seed (fig. XL)..*Capsella Bursa-pastoris* A. Medic. 39
2. Groove not double but running entire length of seed....
.........................*Sisymbrium officinale* Scop. 41
1. Surface without a longitudinal groove starting at one end.
2. Surface finely pitted or with numerous tubercle-like elevations.
3. Surface pitted.
4. Nearly cylindrical, one end smaller than the other, pits deep (fig. XXIV)..........................
...........*Verbascum Thapsus* L. or *Blattaria* L. 74
4. Not cylindrical.
5. A slight groove at one end, grayish brown (fig. XXXIX) ....*Barbarea vulgaris* R. Br. 42
5. Without a groove at one end.
6. Pits quite distinct under a microscope; with quite a pronounced concavity at the scar usually under .9 mm. long.................
...................*Cuscuta epithymum* Murr. 64
6. Pits not markedly distinct; more granular in appearance; not markedly concave at scar but with more marked flattened areas than in next preceding species....*Cuscuta arvensis* Beyrich 65
3. Surface with concentric or eccentric rows of tubercle-like projections.

4. Dark gray or black when mature.
    5. Dull lead-colored, almost circular, not over .5 mm. in diameter............*Arenaria serpyllifolia* L. 28
    5. Almost shiny black, more ovate in shape, over .5 mm. in diameter........*Portulaca oleracea* L. 35
4. Distinctly reddish to red-brown in color.
    5. Over .8 mm. in diameter with 5-6 curved rows of minute tubercle-like projections on each face, dark (fig. XXXIV).....*Stellaria media* L. Cyril. 29
    5. Under .8 mm. in diameter with coarser tubercles, lighter...................*Cerastium viscosum* L. 30

2. Surface smooth, not pitted or tubercled.
    3. Flat, nearly circular without a noticeable notch but with a short projection on the margin and a narrow wing......................*Ranunculus abortivus* L. 36
    3. Not flat, narrow winged or circular.
        4. Dark brown to black, with an oily appearance, under .8 mm. in length, broadly oval.................................*Eragrostis megastachya* Host. 8
        4. Not dark brown to black, usually over .8 mm. long.
            5. Nearly spherical, minutely pitted or with a distinct granular appearance.
                6. Pits quite distinct under a microscope, with a pronounced concavity at the scar, usually under .9 mm. long..*Cuscuta epithymum* Murr. 64
                6. Pits not markedly distinct, more granular in appearance, not markedly concave at scar but with more marked flattened areas than the next preceding species. ....*Cuscuta arvensis* Beyrich 65
            5. Not spherical, pitted or with granular appearance.
                6. Somewhat shield-shaped with a notch at apical end, a slight groove on each side of the notch.
                    7. Green to black........*Trifolium hybridum* L. 48
                    7. Yellowish to light brown..*Trifolium repens* L. 47
                6. Not shield-shaped or with grooves.
                    7. Surface finely hairy, flattened oval, tapering at the base..........*Erigeron canadensis* L. 84
                    7. Somewhat spindle-shaped with a scar at the broader end extending not over one-fourth length of the seed......*Agrostis alba* Schrad. 7

BIBLIOGRAPHY.

Beal, W. J., The Seeds of Michigan Weeds: Bull. 260. Michigan Agricultural Experiment Station. 1910. East Lansing. Michigan.

Brown, E., and Hillman, F. H., Seed of Red Clover and Its Impurities: U. S. Dept. of Agriculture. Farmer's Bull. 260. 1906. Washington. D. C.

Darlington, Wm., American Weeds and Useful Plants: 1858. Orange Judd & Co., New York.

Dewey, L. H., Weeds and How to Kill Them: U. S. Dept. of Agriculture. Farmer's Bull. 28. 1895. Washington. D. C.

Dudley, W. R., The Cayuga Flora. 1886. Andrus & Church. Ithaca.

Engler, A., and Prantl, K., Die Naturlichen Planzenfamilien. 1887. Leipzig.

French, G. T., Seed Tests Made at the Station: Geneva Agricultural Experiment Station. Bull. 333, 1911. Geneva, N. Y.

Garman, H., On Adulterants and Weed Seeds in Kentucky. samples of Blue Grass. Orchard Grass. Timothy. Red Clover and Alfalfa: Bull. No. 124 of the Kentucky Agricultural Exp. Sta., 1906.

Gray, A., New Manual of Botany. 1908. American Book Co., New York.

Harz, Dr. C. D., Landwirthschaftliche Samenkunde. 1885. Berlin.

Hillman, F. H., Testing Farm Seeds in the Home and Rural School: U. S. Dept. of Agr., Farmer's Bull. 428, 1911. Washington. D. C.

Roberts, H. F., and Freeman, G. F., Commercial Seeds of Brome-grass and of English and Kentucky Blue-grasses: Adulterants and Substitutes and their Detection. Kansas Station. Bull. 141. 1907. Manhattan, Kan.

Selby, A. D., A Second Ohio Weed Manual: Ohio Station. Bull. 175, 1906. Wooster, Ohio.

Wilcox, E. M., and Stevenson, N., Report of Nebraska Seed Laboratory: Bull. 110, Agr. Sta., 1908. Lincoln, Neb.

Woods, A. F., The Wastes of the Farm: The Yearbook of the U. S. Dept. of Agriculture. 1908. Washington, D. C.

INDEX.

A HANDY DEVICE FOR STAINING SLIDES.

E. LAURENCE PALMER.

The simple staining apparatus illustrated in the accompanying diagram was devised to take the place of the more expensive staining jars sold by most of the scientific supply houses. Besides the cheapness of the outfit, which fits into any tumbler, there is the added advantage that all of the slides being stained

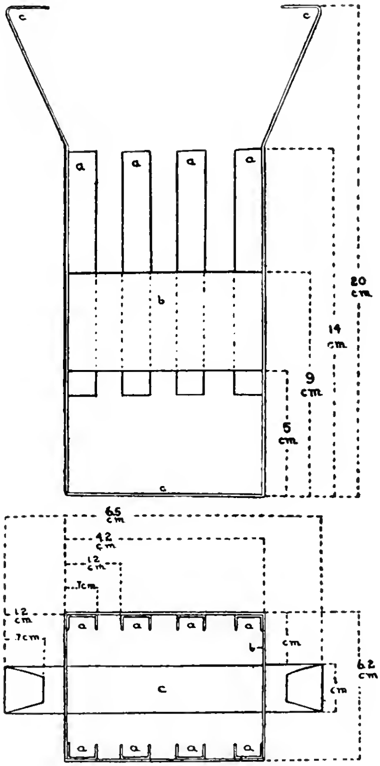


FIG. 45.

may be removed from the jar at once and may be rinsed while still in the frame. Fourteen slides may be inserted into the frame at one time, which is four more than the average staining jar holds.

The device is made by bending eight strips of zinc 15x200 mm. into the channels (a) (figure 45). These are soldered in position according to the diagram. to the 20x140 mm. zinc strip (b) which is then bent into a rectangular form with the channels on the inside. The strip (c) 1x26 cm. is then soldered to the ends of the strip (b) forming a handle with which to lift the frame, and a guard to prevent the slides from falling out at the bottom.

This piece of apparatus has proved particularly handy in staining work where most of the slides require the same treatment.

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A FOREST CENSUS IN LYON COUNTY, IOWA.

DAVID H. BOOT.

The northwest corner of Iowa has comparatively few native trees because of the xerophytic conditions which prevail there. The rainfall of this part of the state is the least in Iowa, at times going as low as eighteen inches for the year, and in exposed regions, the forest trees have been unable to obtain a

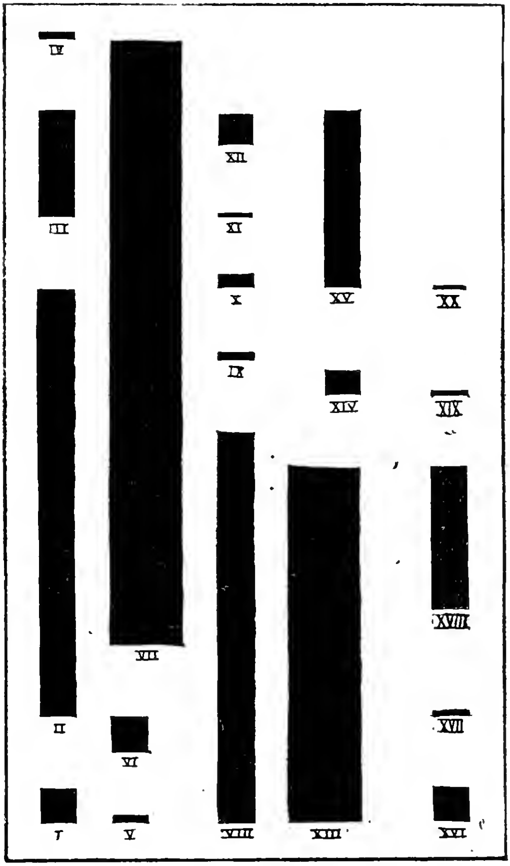
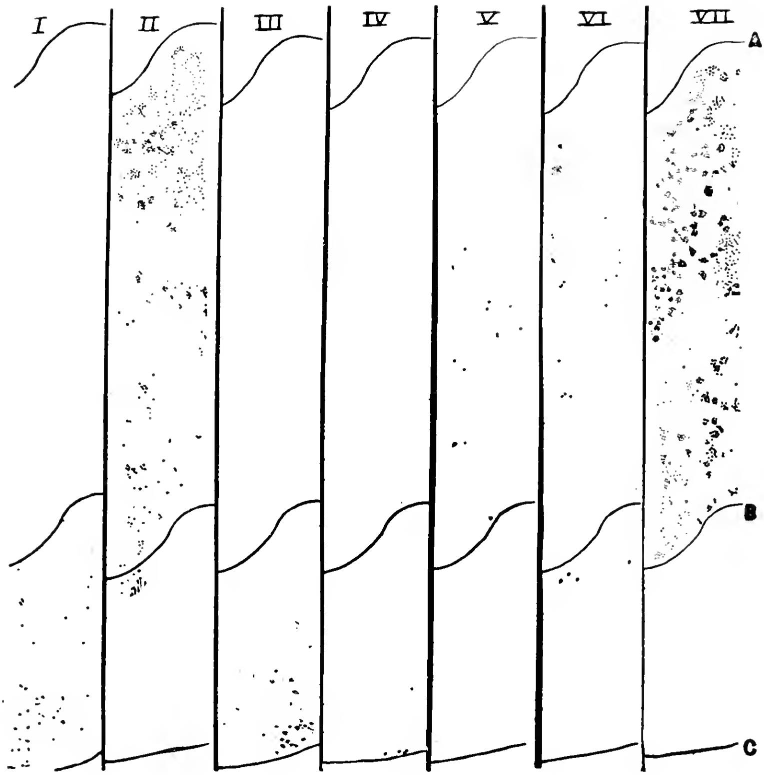


FIG. 46.

footing. The native trees are nearly all found along the streams or in protected valleys. A good illustration of this is in Centennial township in the southwestern corner of Lyon county, where the Big Sioux river flows in a westerly direction for several miles at the foot of a series of high bluffs. The north face of these bluffs is heavily timbered, and is the subject of this paper.

The particular locality chosen was on the south bank of the Big Sioux river at a point known as Syverud Bluff, where the high hills on the south side of the river rise to a height of about 180 feet above the stream. This maximum height is attained at a distance of about one-fourth of a mile south of the river. A typical strip of the timbered land extending from the river south to the bare prairie at the top of the bluff was selected for the survey. This strip was 145 feet wide. The woodland chosen was divided into quadrats, and a careful census made of all trees and shrubs, the size of each being taken, and a special effort made to locate each one accurately. The charts accompanying this report indicate the localities of growth. The list of trees, vines, and shrubs is as shown in the following table, and the accompanying graph, figure 46, indicates proportions.

	Name of Plant	No. of Specimens	Per Cent
I.	Acer saccharinum L. (soft maple)	40	1. +
II.	Ulmus americana L. (American elm)	440	12. +
III.	Salix nigra Marsh (black willow)	117	3. +
IV.	Acer negundo L. (box elder)	9	.2 +
V.	Vitis vulpina L. (wild grape)	13	.3 +
VI.	Fraxinus pennsylvanica var. lanceolata (Birk) Sarg. (green ash)	43	1. +
VII.	Tilia americana L. (Basswood)	1184	34. +
VIII.	Ribes Cynosbati L. (goose berry)	382	11. +
IX.	Alnus sp. (alder)	8	.2 +
X.	Prunus virginiana L. (choke cherry)	16	.4 +
XI.	Rubus idaeus var. aculeatissimus (C. A. Mey) Regel & Tiling (raspberry)	6	.1 +
XII.	Symphoricarpos occidentalis Moench (buck bush)	33	.9 +
XIII.	Ostrya virginiana (Mill) K. Koch (American hop hornbeam)	685	20. +
XIV.	Gymnocladus dioica (L.) Koch (Kentucky coffee tree)	24	.7 +
XV.	Quercus macrocarpa Michx. (bur oak)	190	5. +
XVI.	Crataegus mollis (L. & G.) Scheels (hawthorn)	50	1. +
XVII.	Celastrus scandens L. (climbing bitter sweet)	5	.1 +
XVIII.	Prunus americana Marsh (wild plum)	148	4. +
XIX.	Juglans nigra L. (black walnut)	5	.1 +
XX.	Juniperus virginiana L. (red cedar)	1	.02+
	Total	3399	100.


I
II
III
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The distribution of these trees and shrubs is very interesting and calls for the following description:

Extending south from the Big Sioux to the foot of the bluff is a tract of low river bottom subject to overflow, in width about 350 feet. At the south edge of this flat, the bluff rises abruptly, reaching its crest 1.250 feet south of the river, at which point it has an elevation of about 180 feet. All the soft maple trees (Plate XII, figure I) are located on the river flat, and none of them appear on any part of the bluff. This is to be accounted for because the soft maple is a water lover, and finds an abundance of moisture, and good protection from the dry southwest winds of summer, under the shelter of the bluff. These trees run to large dimensions, some of them being as much as twenty-four inches in diameter. The American elms (Plate XII, figure II), 440 specimens, are divided into four principal groups. The greater part are to be found in the thick timber on the upper third of the bluff face. Below this, there is an interval of several rods succeeded by a considerable interval thickly timbered with the American elm. Then comes another interval without elms, after which they are scattered rather freely down to the foot of the bluff. The fourth group consists of a few scattered individuals located on the river bottom, close to the foot of the bluff, and made up of trees probably seeded from the trees on the bluff face. There is a very conspicuous absence of these trees from the greater portion of the river bottom, which is to be accounted for by the river floods, by the sand and gravel soil, and by the over supply of ground water. The elm's ability to vary its transpiration and to withstand severe evaporating tendencies in environment will be brought out in the records of transpiration and evaporation to appear in another paper.

The black willows (Plate XII, figure III) are one hundred ten in number, all grouped on the low ground near the river, with the exception of a few trees about 100 feet from the river bank. This grouping is readily accounted for by the tree's fondness for water. These trees occur chiefly in clumps surrounding a center where the parent of the group formerly stood.

There are five box elder trees (Plate XII, figure IV), in the tract studied, four of which occur on the edge of the river, and the fifth one some seventy-five feet south of it, but all of them so located on the river bottom that they are certain of an unfailing supply of water. As is well known, this tree adapts itself to varied conditions of climate and exposure when forced to it by artificial planting; but in this study, we consider only undisturbed trees, and these box elders have been planted by nature and grow in a very moist situation.

Eleven grape vines (Plate XII, figure V) are found in the tract, none of them on the river bottom, and none of them on the upper half of the bluff face. They are widely scattered, and evidently avivectant, all of them being located at the foot of trees, up and over which they climb. It is unusual not to find the wild grape on the river bottom nor in the forest on the upper part of the bluff face. For the river bottom this can only be ascribed to the chance work of the birds, with some help possibly toward elimination by the river floods. With the upper bluff face, the absence is probably in part due to over-crowding by other vegetation, as well as to the seed-carrying birds seeking out the lower, more sheltered regions, in the hot months of autumn when the fruit is ripe.

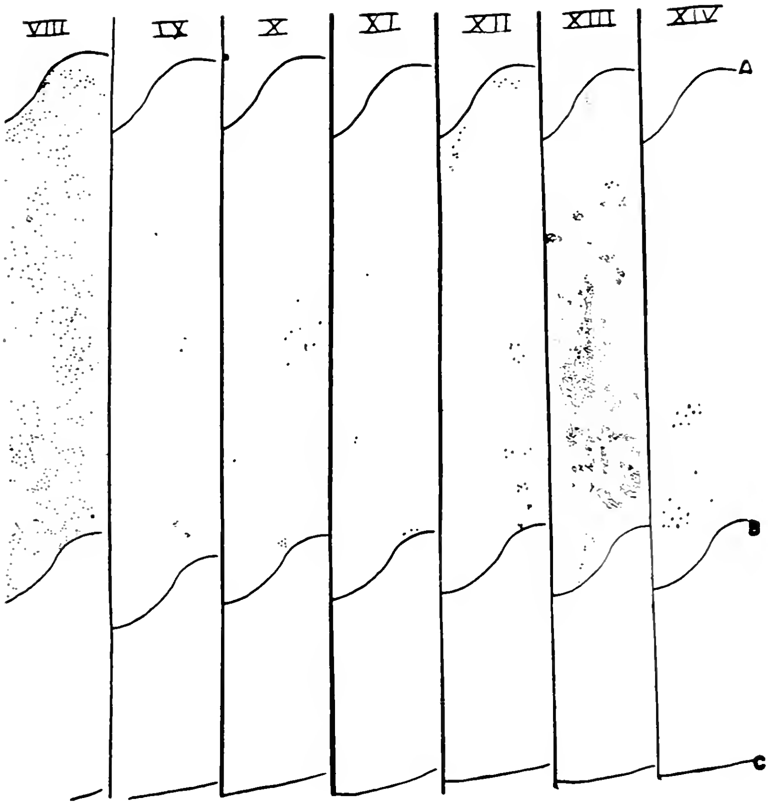
Forty-three specimens of green ash occur (Plate XII, figure VI), three only on the river bottom and close to the foot of the bluff, most of the river bottom being devoid of this species. The next group of them is at a considerable distance up the hill, and after another vacant space of several rods we find two other distinct groups, the one somewhat scattered, the members of the other near together in a manner to indicate that the several trees are the descendants of the same ancestor. Still farther up, and in the drier part of the wood area, we come to two groups, which also indicate by their manner of growth that each group is from one ancestor, and finally, almost at the upper tree limit, where the conditions for tree growth are severe, we find two individuals. Contrary to expectation, the trees at the bottom where moisture is abundant and protection good, do not differ in size very markedly from the trees at the top, where the conditions are more severe, as the largest of them vary from four to six inches in diameter, except in the case of two individuals close to the upper tree limit, which are stunted, and only two inches in diameter. A considerable part of the upper third of the forested area is devoid of ash, since it lacks sufficient moisture and is over-crowded with other vegetation, but lack of moisture cannot be urged for the lower third of the bluff, or for the river bottom, and crowding can play no part in the distribution on the river bottom, because the forest there is thinly scattered. In place of over-crowding there, we have the river floods acting as a destructive agent when they periodically inundate this land.

Nearly twelve hundred bass wood trees (Plate XII, figure VII) grow in the region studied. None of these are found on the river bottom. On the bluff face they are scattered quite regularly from almost the foot of the bluff to within a distance of two to five rods of the upper tree limit, with the exception of an area about five rods wide a little below the middle of the forested tract. A most noticeable thing with the bass wood is the "family group," as it might be called, in which a considerable number of individuals are clustered about the grave of the parent from which they sprang. While the bass wood is able to adapt itself to great variations in growing conditions, it shows plainly by its development the influence of those conditions, as the largest and tallest trees are found near the foot *of the bluff, where they are well protected. A large number of the trees at the upper limit of their growth do not run more than one or two inches in diameter.

There are three hundred eighty-two gooseberry bushes (Plate XIII, figure VIII) in the tract. None of them occur on the river bottom, but they are distributed with a fair degree of equality from the foot of the bluff almost to the upper limit of the forest, with the exception of several large spaces a little below, and also a few a little above, the middle of the forest, where they are probably crowded out by other vegetation. In some cases, groups of these bushes indicate by their arrangement that they are from one parent plant.

There are eight elder bushes in this tract (Plate XIII, figure IX), located in two groups not far apart, near the mouth of a gully at the bottom of the bluff, where they are well protected, and receive abundant moisture. The arrangement of the members of these two groups is such as to show that each group is from a single parent that formerly stood at this spot. We may attribute their absence from the river flat to the flood waters of the river, and their absence from the upper parts of the wooded bluff to insufficient moisture.

There are sixteen choke-cherry trees (Plate XIII, figure X), one group of which is found on the escarpment at the foot of the bluff, about ten feet above the river flat. These are in a close


VIII
IX
X
XI
XII
XIII
XIV
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group indicating common ancestry. The second group is somewhat scattered near the middle of the west side of the area. None of these trees occur in the upper half of the forested area, and none of them occur on the river bottom. They appear to seek the medium conditions as to moisture and shelter, and the scattered ones are apparently avivectant.

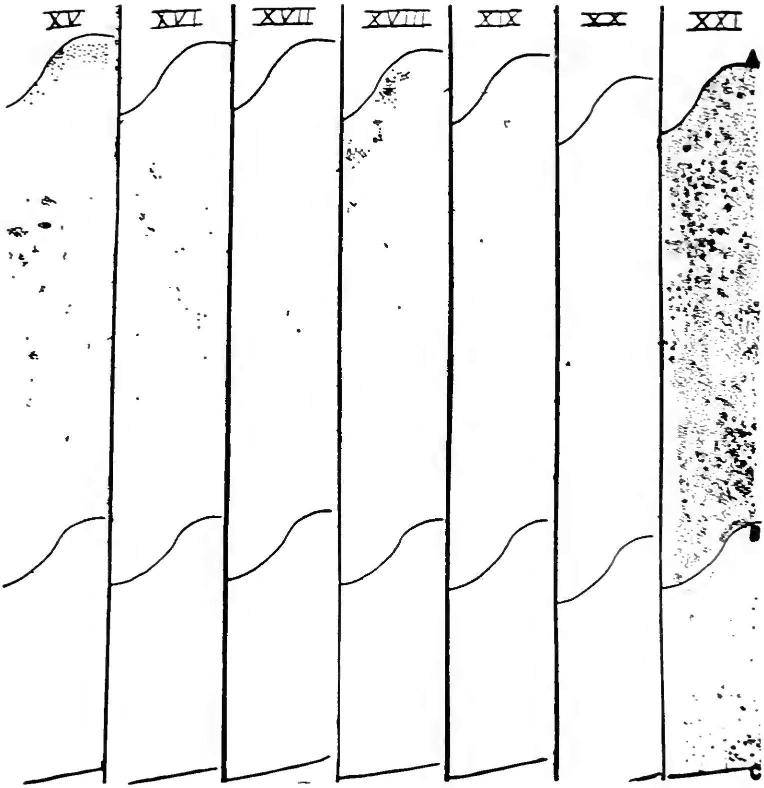
There are six raspberry bushes (Plate XIII, figure XI) distributed, three of them in the upper section, and three in the middle, of the lower part of the wooded bluff face in such a way as to indicate that they are planted by birds.

Thirty-three buck bushes (Plate XIII, figure XII) occur, distributed in three groups, one group, in two parts, near the upper limit of tree growth, another near the middle of the west side, the third a short distance above the foot of the bluff. This distribution may be taken to show ability in this plant to adapt itself to considerable ranges of humidity and exposure, and, in the lower groups at least, it is apparently the work of birds. The bush does not occur at all on the river bottom where the conditions affecting plant life are such as to require the ability to handle much moisture.

Six hundred eighty-five hop hornbeam trees (Plate XIII, figure XIII) appear in the tract. None of these trees are on the river bottom, and the greater part of them are grouped in close associations on the lower half of the bluff face. Some of these groups indicate a distribution from a common center, a parent tree. Vacant areas among them are to be attributed to over-crowding by other trees. Some of these trees are found in the upper part of the forest, and one small group occurs near the upper forest limit, showing that they are able to adapt themselves when necessary to considerable variation in conditions. None of these trees are large, as large size would be impossible because of their crowded manner of growth.

Twenty-four Kentucky coffee bean trees (Plate XIII, figure XIV) occur on the bluff face not far from its foot. This tree grows to considerable size and in this place has good protection and plenty of moisture, but is unable to survive the very wet conditions of the river flat.

Only one red cedar grows in this piece of timber (Plate XIV, figure XX), and it is a small one of only one-half inch diameter, found in an opening among the bass woods and hop hornbeams,



so abundant about the middle of the bluff face. Red cedars are uncommon in this part of the state, this being the only one found in several years' work along the Big Sioux river in Lyon county.

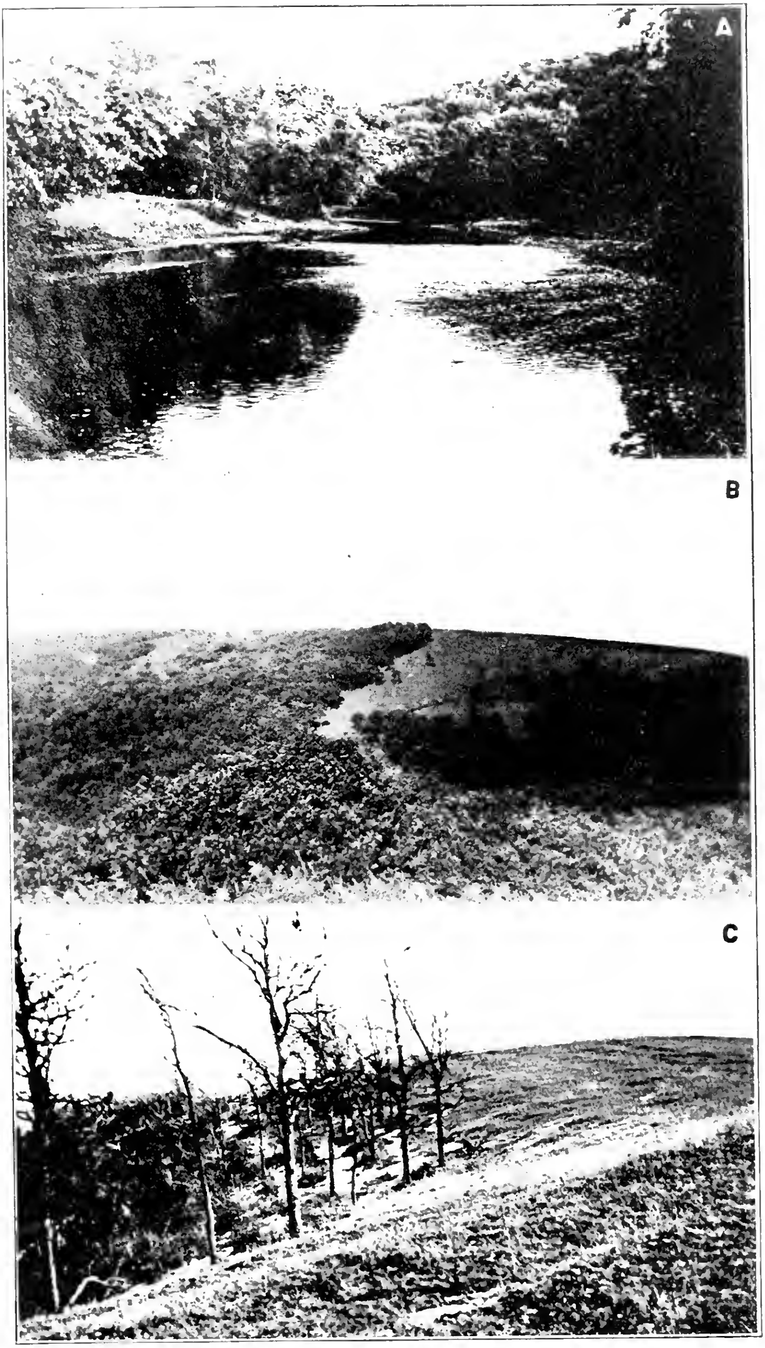
The one hundred and ninety bur oak trees (Plate XIV, figure XV) are arranged in two very significant groups, one of which is further subdivided in a characteristic manner. One group is near the top of the bluff, and comprises about seventy individuals. They are almost the extreme outposts of the xerophytic trees, crowding up close to the bare prairie. The remainder of the oaks are located chiefly near the middle of the north slope of the bluff, and are in about ten small clusters, plainly indicating by their grouping a common origin for the separate clusters. It is probable that a parent tree supplied acorns for each separate group. The great ability of the bur oak to adapt itself to extreme variations in humidity and water supply does not come out as strikingly here as in many other localities, for there is a total lack of these trees on the river bottom.

There are fifty hawthornes (Plate XIV, figure XVI), all located near the middle of the forest, none of them going as high as the extreme top of the hill, nor as low as the lower third of the hill, and they do not occur on the river bottom. Most of them are found in half a dozen clusters indicating centers of distribution, but about ten are scattered as if planted by birds.

Three climbing bitter-sweets (Plate XIV, figure XVII) are found near together at the midde of the woods. From their habitat at the foot of trees, they probably have been planted by birds.

There are about one hundred and fifty wild plum trees (Plate XIV, figure XVIII), none of them found on the river bottom, nor on the lower half of the hill, and nearly all within forty yards of the upper tree limit. They are grouped in thickets indicating their common origin from parent trees, and the method of propagation by suckers and fallen fruit. A very few scattered trees probably have been planted by animals. This tree is one of the hardier of the forest inhabitants, able to endure the severe conditions near the upper tree level.

Five black walnut trees (Plate XIV, figure XIX) occur, four in one group within thirty yards of the upper tree level, and one solitary specimen about one-third the way down the hillside. The group of four appear to have a common origin, the seed of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all of them probably having been planted by the same squirrel. It is rather remarkable that these trees should be found in this part of the wood only, and none lower down, especially on the river bottom.

Figure XXI of Plate XIV shows the entire forest. It will be noticed that the river bottom is thinly forested, that most of the trees on it are found close to the river, and that large tracts are devoid of arboreal vegetation. The face of the bluff is densely covered from its foot to the upper tree limit, excepting small openings here and there, usually not more than two or three rods in diameter. Looking at the chart the forest appears very uniform, and it is only when one goes out into the field that the great difference due to the different species of trees, and to the different conditions of growth becomes apparent, the lower forest (Plate XV, figure A), being very dense and heavy, and the upper forest lower and less dense, as will be seen in the accompanying photographs (Plate XV, figures B and C). The effect of environment in selecting the forest trees of a locality clearly appears in this tract. Figure 47 is a sketch of the bluff, giving elevations and

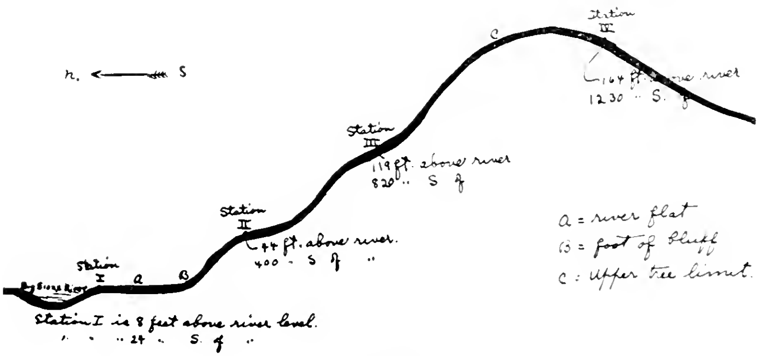


FIG. 47.

distances. The observations on the herbaceous plants, on evaporation, transpiration, and meteorological conditions made at this point during three years will appear in another paper.

DEPARTMENT OF BOTANY,
STATE UNIVERSITY.

SCLERODERMA VULGARE AND ITS IOWA ALLIES.

GUY WEST WILSON.

The Sclerodermitaceæ, or so-called hard puffballs, have been very inadequately studied by American mycologists. Indeed it has been too common a custom to group all the material together as *Scleroderma vulgare* Hornem, without regard to external markings, the thickness of the periderm, or the mode of rupture for spore dispersal. Probably one of the most comprehensive treatments of the American forms is that by Lloyd[1] in connection with his studies on Australian species. His treatment has been followed with some variations by Hard[2] and by McIlvane[3], each adding variations to the treatment of species. Several of the eastern forms have ben figured by Murrill in Mycologia. However, no systematic account of the American forms has come to the notice of the writer.

As treated by Ed. Fischer[4] the American members of the family fall under three genera, *Scleroderma*, *Pisolithus*, and *Sclerangium*. Of these the first and second rupture irregularly for the dispersal of the spores, while in the third the periderm breaks into stellate lobes as in *Geaster*. Usually the spore mass is exposed directly, but occasionally specimens are found with a very delicate and evanescent inner periderm. In *Scleroderma* the periderm varies in thickness in different species but it is always more permanent than in *Pisolithus*. The hymenial, (glebal) characters are also of considerable interest and subject to a wide range of variability. At first the hymenial surface is broken up into a series of closed chambers which are irregulary disposed among the sterile tissues of the sporophore. In *Scleroderma* these lose their individuality with the maturity of the sporophore, although they frequently remain as distinct lines of hyphae which gives the spore mass the appearance of being contained in numerous small pockets. In *Pisolithus* these chambers are persistent in the mature sporophore as peridioles quite similar in appear-

[1]The Lycoperdonaceæ of Australia, New Zealand and neighboring islands, 1905, pp. 12-15, pl. 29-31.
[2]The Mushroom, 1908, pp. 555-558, 567.
[3]One Thousand American Fungi, Revised edition, 1912, pp. 615-618.
[4]Engler & Prantl, Natürl. Pflanzenfam., 1899-1900, 1[1]**: 331-338.

ance to those of the Nidularaceæ. This character is subject to a very wide range of variation so that in some cases it is necessary to rely entirely on the peridium to determine to which genus a given specimen should be referred.

KEY TO THE SPECIES.

Distinct peridioles absent at maturity; periderm rather persistent.
  Periderm rupturing irregularly.
    Periderm thick.
      Periderm conspicuously warty or scaly....................
      ....1. *Scleroderma aurantium*
      Periderm smooth, or smoothish............2. *Scleroderma Caepa*
    Periderm thin.
      Periderm rather firm and flexible, smooth or scaly.........
      ....3. *Scleroderma Bovista*
      Periderm fragile above, warty........4. *Scleroderma verrucosum*
  Periderm rupturing stellately.
    Spore-mass light colored..................5. *Sclerangium flavidum*
    Spore-mass appearing almost black.....6. *Sclerangium polyrhizon*
Distinct peridioles present at maturity; periderm very fragile....
    ....7. *Pisolithus arenarius*

I. SCLERODERMA Persoon.

Sporophore subglobose, with rhizomorphs and frequently rhizoids, or even a stalklike base; peridium single, usually thick, rather firm, opening irregularly; gleba homogeneous, capillitium none, the boundaries of the spore cavities remaining as more or less distinct lines of hyphæ; spores globose, roughened.

1. SCLERODERMA AURANTIUM (L.) Pers. (*S. vulgare* Hornem.)

Subglobose, subsessile, radicate or not, 2.5—8 cm. in diameter; periderm thick, corky, usually pale with shades of yellow or orange, or sometimes brownish, usually covered with large warts which are more or less deciduous; gleba at first white, changing through various shades to blue-black and finally greenish gray; lines of trama yellowish; spores dark, globose, warted, 7—12 μ in diameter.

Johnson county (Macbride, Shimek, Miss Jewett), Linn county (Shimek), Muscatine county (Shimek).

The commonest species in our territory and one of the largest. It presents a considerable variation in the size and pattern of the warts on the periderm. The specific name is frequently incorrectly written "aurantiacum."

2. SCLERODERMA CAEPA Pers.

Subglobose or depressed, 3—8 cm. diam.; peridium smooth or only slightly roughened, never truly tuberculate, thick and firm; gleba at first white, finally ferruginous; trama lines light yellowish; spores dark, globose, tuberculate, 7—12μ in diameter.

Johnson county (Shimek), Hesper, Winneshiek county (Shimek).

Very similar to *S. aurantium* but with a slightly thinner periderm which is essentially smooth or only slightly roughened.

3. S. BOVISTA Fries.

Sporophore subglobose, 3—5 cm. diameter, yellowish in color; periderm rather thin and firm, flexible, smooth or somewhat scaly; gleba at first white, at last brownish; lines of trama ochraceous; spores globose, verrucose, 7—12 μ diameter.

Johnson county (Macbride, Shimek), Muscatine county (Shimek).

A very distinct form which appears to be fairly common. It is easily distinguished by its firm, flexible periderm.

4. S. VERRUCOSUM (Bull.) Pers. (*S. tenerum* Berk.)

Sporophore subglobose, 2.5—7 cm. diameter, ochraceous, purplish, or dingy brown; periderm thin and fragile above, firmer beneath, covered with more or less angular warts, continued below into a more or less stemlike base; gleba white, then very dark vinous or almost black, at last umber; lines of trama white; spores globose, dark, warted, 7—12 μ in diameter.

Unionville, Appanoose county (Shimek), Hesper, Winneshiek county (Shimek), Mason City, Cerro Gordo county (Shimek).

A widespread and rather common species which might easily be passed over as immature specimens as it ranges quite small in our territory. The thin, fragile periderm distinguishes it readily from *S. aurantium*. The white trama lines also are quite distinctive. Probably second only to *S. aurantium* in commonness.

II. SCLERANGIUM Leville.

Similar to Scleroderma except that the periderm ruptures stellately, sometimes exposing a thin inner periderm.

5. S. FLAVIDUM (Ellis & Everh.) nom. nov. (S. Wrightii f. flavidum Ellis & Everh.)

Sporophore depressed-globose, yellowish; peridium thick and firm, scaly, especially above, splitting stellately into three to eight triangular lobes; spore-mass at maturity umbrinous, or shading towards brown; lines of the trama light [illegible]; spores globose, roughened, 7—13 μ in diameter.

Johnson county (Wilson).

Differs from S. [illegible] in its mode of rupture and from S. [illegible] in its smaller size, its lighter color and the lighter colored spore mass.

6. S. POLYRHIZON (Gmel.) Lev. (S. [illegible] Geaster Fries.)

Sporophore rather large, [illegible] cm. in diameter, yellowish brown to greenish brown; peridium thick, smooth, splitting stellately into three to six teeth; inner peridium if present very thin and fragile; spore-mass very dark, appearing almost black; lines of trama whitish; spores globose, dark, coarsely warted, 12—14 μ in diameter.

Johnson county (Macbride).

A very distinct and striking species which upon rupture bears a superficial resemblance to an earth star (*Geaster*).

III. PISOLITHUS Alb. & Schw. (Polysaccum DC.)

Resembling Scleroderma, but with a thin and fragile peridium and persistent peridioles.

1. P. ARENARIUS Alb. & Schw. (Polysaccum pisocarpium Fries.)

Sporophore depressed-globose, with a prominent root-like base; peridium smooth, dark brown, fragile and thin, breaking irregularly, showing within [illegible] peridioles, polygonal [illegible] brown or reddish brown; spores brown, [illegible] warts.

This species would readily be passed over in the field as a Scleroderma, but even a superficial examination shows its marked characters separating it from that genus. This is a very rare species in America and is included here provisionally on the basis of a specimen in the University herbarium bearing the locality data "Hopkinton [illegible]" [illegible] that it was probably collected at [illegible] in Winneshiek county by Professor Shimek. Its [illegible] with considerable interest.

DEPARTMENT OF BOTANY,
STATE UNIVERSITY OF IOWA.

NOTES ON SOME PILEATE HYDNACEAE FROM IOWA.

GUY WEST WILSON.

The Hydnaceæ, or spine fungi, is one of the smaller families of the Agaricales, or, as they were known to the older mycologists, the Hymenomycetes, numbering as it does only about five hundred species. Of these some are widely dispersed and rather common while others are quite sporadic or even local in their occurrence. Only a few members of the family are common in our state, yet their number is more considerable than the published accounts would indicate, as but four species appear to have been recorded from Iowa. Greene in his Plants of Iowa does not even mention the family, while two other papers, one by Hess and Vandivert[1] and one by Shimek[2] include a single species each. The most considerable list of Iowa species is given by Banker[3] who includes references to three. The present paper includes fifteen species, all but one of which are represented in the herbarium of the State University.

The taxonomic treatment of the Hydnaceæ, in common with that of related families, has been subject to various vicissitudes both as to extent of the group and as to the arrangement of the species. Under the old concept two types of pileate forms were included. Those forms having the teeth at least approximately terete were all referred to the genus *Hydnum*, while those with decidedly flattened teeth were designated as the genus *Irpex*. The present paper is concerned only with the pileate species of the first group. Numerous attempts have been made to segregate the old genus *Hydnum*. As might be expected these have met with varying degrees of success or failure according to the grasp which their author had upon the relative importance and taxonomic value of the characters which were employed. Perhaps the most rational attempt at a revision of the group is that of Banker[3] who in his careful treatment of the American species

[1]Hess and Vandivert. Bacidiomycetes of central Iowa: Proc. Iowa Acad. Sci., VII, 1900, 183-186, pl. 16.

[2]Shimek, The Plant geography of the Lake Okoboji region: Bull. Labs. Nat. Hist. Univ. Iowa. 7[2]. 1915, 1-90, pl. 1-8 and map.

[3]Banker. A contribution to the revision of the North American Hydnaceae. Mem. Torrey Club. 12, 1906, 99-194.

has laid the foundation for a satisfactory revision of the entire family. The primary characters used are not merely colors and superficial external resemblances which might be accidental, but a series of correlated characters so based upon the entire fungus as to insure a workable and logical grouping of species. Those members of the group which have smooth spores also have light colored flesh and lend themselves to further segregation on the basis of habit, of hymenial structure, and of habitat, while those species with roughened spores have darker flesh and may be further segregated on the basis of spore markings, spore color, texture, and habit. This classification is accordingly adopted in the present paper as it represents a grouping of species on the basis of relationships and in a manner such as to make the family more easily studied than to follow some of the earlier writers.

KEY TO SPECIES.

Hymenophore usually light colored, white to reddish or gray; spores smooth, hyaline.
- Terrestrial; hymenophore stipitate, fleshy....1. *Hydnum repandum*
- On wood; hymenophore sessile, dry or fleshy (in No. 6 sometimes stipitate, but not fleshy).
  - Hymenophore more or less tuberculiform or branched, fleshy to sub-fleshy, white or yellowish.
    - Pileus more or less branched from the base.
      - Teeth uniformly distributed over the entire under surface of the branches................2. *Manina flagellum*
      - Teeth so distributed as to leave a bare region at the base of the branches..............3. *Manina coralloides*
    - Pileus more or less massive and tubercular, unbranched ....4. *Manina cordiformis*
  - Hymenophore pileate to resupinate, sessile or stipitate.
    - Substance dry.
      - Pileus sessile and decurrent to resupinate, more or less gregarious and confluent.....5. *Steccherinum ochraceum*
      - Pileus more or less stipitate or subsessile.
        - Hymenophore large and complicated, even stipitate forms often confluent; teeth straight............ ....6. *Steccherinum adustum*
        - Hymenophore smaller and simple, rarely totally confluent, teeth flexuose........7. *Steccherinum pusillum*
    - Substance fleshy.
      - Surface densely strigose to tomentose, gummy when dry ....8. *Creolophus pulcherrimus*
      - Surface rather smooth, white, not drying gummy...... ....9. *Creolophus cirratus*

Hymenophore usually dark colored, terrestrial; spores roughened.
Hymenophore normally pileate and stipitate.
Stipe central; spores coarsely tuberculate, colored.
Surface of pileus obscurely or not at all zoned, more or less uniform in color.
Brown; pileus obscurely zonate, more or less deformed ....10. *Hydnellum scorbiculatum*
Cinnamon-colored ....11. *Hydnellum velutinum*
Surface of pileus zonate.
Small; pileus less than 4 cm. wide, very thin........... ....12. *Hydnellum parvum*
Larger; pileus 3-15 cm. wide, rather thick............. ....13. *Hydnellum zonatum*
Stipe lateral; spores hyaline..........14. *Auriscalpium vulgare*
Hymenophore sessile to resupinate, of branched processes, clothed with a dense coat of branched hairs.......... ....15. *Gliodon strigosus*

I. **HYDNUM** L.

According to the present treatment this genus is limited to those stipitate, terrestrial species with smooth, light colored or hyaline spores and light to yellowish or reddish flesh. We have a single species.

1. H. REPANDUM L.

A cosmopolitan species of extreme variability which is found on the ground in woods from midsummer to autumn. When growing the fungus is light in color, varying from creamy to tawny. Both collections listed here appear to belong to this species, although the second does not agree in all respects with the first, as the individuals are a trifle more robust and the teeth slightly more slender.

Johnson county (Macbride). Hesper, Winneshiek county (Shimek).

II. **MANINA** Scop.

Characterized by having a fleshy tuberculiform or branched, laterally sessile or subsessile pileus; the teeth pendant; spores smooth; the sporophore always light colored, varying from white to creamy, with a more or less coralline or beardlike appearance, always on wood.

We have three species, the nomenclature of which is very much involved owing to the widespread misinterpretation of specific limits. The confusion has been increased by the fact that the genus has been thrice named, and each time confusion introduced into the synonomy of the species. The synonomy is *Manina* Scopoli 1772, *Hericium* Persoon 1794, and *Medusina* Chevelier 1826. The synonomy of our American species has been discussed by Banker.[4]

2. M. FLAGELLATUM Scop. (*Hydnum laciniatum* Leers, *H. coralloides* "Aut.")

One of our commonest and most variable species. The specimens range from large and rather stout to comparatively slender and delicate forms, probably fairly well representing the variations of the species in Iowa. This species is easily distinguished from the next by the distribution of the spines on the branches of the pileus. In the present species they are evenly distributed from tip to base of the branches while in the next they are grouped at the tip, leaving the under side of the branch bare at the base. However, this is the species which is commonly referred to by American mycologists as *Hydnum coralloides* and figured under that name by Hess and Vandivert.[5] The confusion arises from the fact that two closely related species have been assigned the same binomial by different authors, nor is its persistence a matter of surprise as the present species is decidedly more coralline in appearance than is the next.

Johnson county (Macbride); Wildcat Den, Muscatine county (Shimek); Highlandville, Winneshiek county (Shimek).

3. M. CORALLOIDES (Scop.) Banker. (*Hydnum coralloides* Scop.)

Apparently a much less common species than the preceding. This may be due to a failure to discriminate between species in the field, but this appears improbable as one would expect equally common species to be more equitably represented even though their distinctive characters might have escaped notice at the time of collection. American mycologists have sometimes confused this species with the more massive *Hydnum Caput-ursi*. But two specimens seen, one of them from an oak stump.

Iowa City, Johnson county (Wilson); Hesper, Winneshiek county (Shimek).

[4]Banker, Type Studies in the Hydnaceae: I. The Genus *Manina*. Mycologia, 4, 1912, 271-278.

[5]Loc. cit., p. 186, pl. 16, fig. 2.

4. M. CORDIFORMIS Scop. (*Hydnum Erinaceus* Bull.)

A common species, at least locally, which differs from our other species of the genus in its unbranched, tubercular pileus and shaggy spines which give the fungus a rather pronounced beardlike appearance. This fungus cannot well be confused with any other Iowa species. On living and recently cut oak, causing a serious heart rot which finally results in a hollow trunk. All our material appears to be local.

Johnson county (Macbride, Shimek, Wilson).

III. STECCHERINUM S. F. Gray.

A group of species of exceptional variability in form and habit, ranging from pileate to laterally sessile, or even resupinate. The spores are smooth and light-colored, while the context is tough and fibrous. Always on wood. We have three species.

5. S. OCHRACEUM (Pers.) S. F. Gray. (*Hydnum ochraceum* Pers.)

A common and variable species which appears to be confined to dead oak wood. The sporophores may be single or imbricate, often confluent, sessile to decurrent or even resupinate. The surface of the cap suggests a polypore of close relationship with *Polyporus pergaminus*, while the ocher-colored spines are equally characteristic. This is the only species which the writer has found twice referred to in literature as having been collected in Iowa. Banker[6] records it among the species which Holway collected, and Shimek[7] records it from the Okoboji region. These citations would indicate that it is well distributed throughout the state.

Iowa City, Johnson county, (Macbride, Wilson); Okoboji region, Dickinson county (Shimek).

6. S. ADUSTUM (Schwein.) Banker. (*Hydnum adustum* Schwein.)

A very peculiar and interesting species which shows a wide range of variability in form and habit. The hymenophore may be sessile or stipitate, separate or more or less laterally connate, or even developing a "two-story" habit of imbricate pelei.

[6]Mem. Torrey Club, 1906, 12, 125.
[7]Loc. cit., p. 54.

With such a range of variability the form of the pileus could scarcely be expected to show a considerable degree of regularity. The surface is more or less distinctly zonate. The dried specimens are buff or with a tinge of blue above while the teeth have a pronounced bluish tinge in most specimens. All our material is local, although Banker[8] records it as being among the Holway material. On decaying branches.

Johnson county (Macbride, Shimek).

7. S. PUSILLUM (Brot.) Banker. (*Hydnum pusillum* Brot.)

A species quite similar to the preceding, but more conspicuously zonate and with noticeably smaller teeth. Two collections have been seen, both from dead wood, in one instance with fragments of charcoal adhering to the fungus. Previously reported only from New York and New Jersey.

Johnson county (Macbride).

IV. CREOLOPHUS P. Karsten.

The species of this genus differ from *Steccherinum* primarily in their fleshy texture as distinguished from the dry and tough character of the members of that genus. We have two species.

8. C. PULCHERRIMUM (Berk. & Curt.) Banker. (*Hydnum pulcherrimum* Berk. & Curt.)

Two specimens in the University herbarium labelled "immature" and referred questionably to *Hydnum flabelliforme* Berk. are apparently identical and are to be referred here. If this identification is correct we have a considerable extension of range for the species to the northwest. These specimens have a pronounced tawny-colored, gummy pileus. Two specimens which are much larger and with spines a trifle longer, but with very little of the gummy character of the pileus are also referred here provisionally. As it may be that two closely related species have been confused the two series are listed separately, the gummy ones being designated I, and the others II.

I. Johnson county (Macbride). II. Iowa City, Johnson county (Macbride), Dubuque county (Shimek).

9. C. CIRRATUS (Pers.) (*Hydnum cirratus* Pers.)

Not uncommon in Johnson county on oak. The form is easily separable from *C. pulcherrimum* by the lack of gum on the dried pileus, and from *C. septentrionalis* by its less fleshy texture. It also differs in form from these species. When fresh

[8] Loc. cit., p. 132.

the pileus is subfleshy, becoming fragile on drying. The sporophore is broadly effused, approaching resupinate, and not truly imbricate. The statement by Banker[9] concerning " *H. cirratum* Pers. often written incorrectly *cirrhatum*" that "it seems probable that the plants thus reported are *H. pulcherrimum* or *H. septentrionale*" needs no further comment than his previous statement that he has seen none of the specimens so referred. Certainly our own material could never be confused with either of these nor does it agree with any other species listed by Banker.

Johnson county (Shimek, Wilson).

V. HYDNELLUM P. Karsten.

A well defined group of species having coarsely tuberculate, colored spores, and a central stipe which is always duplex in texture, the central region being quite hard while the cortical layers are feltlike. The pileus is fibrous and tough. All four of our species are terrestrial.

10. S. SCORBICULATUM (Fries.) Banker. (*Hydnum scorbiculatum* Fries.)

The collection referred here contains two specimens which are somewhat zonate, but with the teeth decidedly decurrent on the stipe. The pileus is quite noticeably deformed on the upper surface and has a broad sterile margin. The sporophores are rather small.

Johnson county (Macbride).

11. S. VELUTINUM (Fries.) P. Karsten. (*Hydnum velutinum* Fries., *H. spongipes* Peck.)

Two collections of a large cinnamon-colored species with a very pronounced felty layer about the stipe are very evidently this species. The pileus is quite thick, the surface very uneven, and the outline quite irregular. The teeth are only slightly decurrent.

Johnson county (Macbride).

12. H. PARVULUM Banker.

A single collection of five very small sporophores is the sole representative of this species seen. The very small and extremely thin pileus distinguishes this species from *H. zonatum* with

[9] Loc. cit., p. 135.

which it is usually confused. The recorded range is New York, Michigan and Alabama.

Coufal, Johnson county (Miss Macbride).

13. H. ZONATUM (Batsch) P. Karsten (*Hydnum zonatum* Batsch.)

Also represented by a single collection which includes but one sporophore. While apparently very close to the last species it is very easily distinguished from it by the larger and thicker pileus.

Hesper, Winneshiek county (Shimek).

VI. **AURISCALPIUM** S. F. Gray.

In the present genus the pileus has a deep sinus on one side with the stipe so inserted in the sinus as to give it a lateral appearance while the stipe continues on the top of the pileus as a distinct ridge which runs out gradually, but extends well across the pileus. A very interesting monotypic genus.

14. A. VULGARE P. Karsten. (*Hydnum Auriscalpium* L., *A. Auriscalpium* S. F. Gray.)

This species is recorded from Iowa by Banker[10] who gives its habitat as "decaying cones of Conifers." Our specimens are probably from the same collection as his Iowa material, but do not show the substratum further than that the base of the stipe is covered with moss. The label reads "On the ground. Rare." Not to be confused with any other species of the family on account of the peculiar insertion of the stipe.

Iowa (Macbride).

VII. **GLIODON** P. Karsten.

A very distinct genus characterized by the papillate, light-colored spores and the sessile or resupinate branched pileus. Monotypic.

15. G. STRIGOSUM (Swartz) P. Karsten. (*Leaia piperata* Banker, *Hydnum strigosum* Swartz.)

Not represented in the University herbarium but recorded by Banker[11] as being collected in Iowa by Holway.

Department of Botany,
State University.

[10] Loc. cit., p. 178.
[11] Banker, loc. cit., p. 176.

PIONEER PLANTS ON A NEW LEVEE—II.

FRANK E. A. THONE.

A year ago the writer presented before the meeting of the Academy at Iowa City a paper under the above title[1] describing the vegetation appearing during the first growing season on a newly built embankment in Des Moines. It was his intention to make this the first of a series of studies following the development of the flora on this area until a permanent balance of power had been established.

Unfortunately, however, several circumstances intervened to prevent the carrying out of this plan. The writer was able to visit the area only a few times after the completion of the first paper, and the information gleaned on these flying visits covers only the most salient facts. In the second place, the river itself has made a number of changes in the terrain. The level space that originally lay between the foot of the embankment and the edge of the channel has been entirely eaten away, and in one place a portion of the levee itself has slid into the river. On the opposite shore the erosion has been even more rapid; the entire face of the sand heaps described in the previous paper has disappeared, and on the continually slipping, almost perpendicular wall of sand that remains no living thing has so far been able to establish a foothold. And since the two bridges which formerly connected the newly made island on which these sand heaps lie with the mainland have been destroyed, the reverse slopes are as much of a *terra incognita* as the other side of the moon. Finally, the western end of the levee has been graded and everything there is reduced to hopeless chaos.

There remains, then, only the actual embankment of the levee proper in anything like its original shape, and here alone conditions have taken their normal course, so that it is only on this part of the entire original area that any observations at all were worth while.

[1]See Iowa Academy of Science Proceedings, Vol. XXII, p. 135.

On this area the weeds have succeeded very well for one year's work, and have made conditions much more comfortable for themselves. They have bound at least the surface soil with their roots, so that there is much less washing than there was during the preceding season. The presence of algae and mosses, and of a few specimens of *Equisetum arvense*, testify to improved moisture conditions. Some of the plants first observed (notably the survivors of the former cultivated state) have disappeared; lack of time for careful botanizing has prevented the preparation of a list of the missing. Most of the plants still remain and thrive, however, and a few new arrivals may be reported. Two of them, *Salsola tragus* and *Lepidium virginicum*, were probably rolled in as tumbleweeds from the railroad embankment against which one end of the levee abuts; the remainder (listed below) were probably wind-sown.

The main point of interest in this year's observation, however, is concerned with the changes of dynasty which are taking place in this little corner of the vegetable kingdom. In the first paper the pigweed, *Amaranthus retroflexus*, was reported as the dominant plant. A prolific seeder, holding moreover a goodly proportion of its offspring until well into the following growing season before launching them on their colonizing ventures, it was well prepared to become master of the situation presented by the newly bared soil exposed after spring was well advanced. With it, as noted before, went the goosefoot, *Chenopodium album*, which possesses some of the same characteristics. A considerable sprinkling of this plant was interspersed with the dominant amaranth, but the amaranth remained after all the king of the colony during the first season.

But with the arrival of the second spring the situation was radically changed. The *Chenopodium* proved to be an early riser, and thus got the start of its cousin weed. During the latter part of March the writer went over the ground, and the principal sign of life on the levee was the presence of *Chenopodium* seedlings all over the place. They were as ubiquitous as the *Amaranthus* had been during the preceding season, and in places formed dense sods. No seedlings of the pigweed were as yet to be seen. Observations a couple of months later showed the logical result. The dominant plant was now the *Chenopo-*

dium, and specimens of *Amaranthus* were few and far between. Handicapped from the start, only a scattering stand had developed, and these poor individuals were having a hard fight for existence. Shouldered and smothered by their neighbors, they showed little trace of the sleek prosperity that had been the lot of their parents the summer before: the kingdom of the amaranth was at an end.

But even then a new race was beginning to rear its head among the ranks of the Chenopodium: a possible rival that might drive it, in its turn, into extinction. During the second summer a few specimens of *Lactuca scariola* were observed on the area. They maintained their place and bore their seed, so that by the latter part of the summer the winter rosettes of this plant were showing themselves wherever there was an inch of free ground, and they even established themselves between the stalks of the *Chenopodium* where it was not too thick. Long after the early frosts and snows had killed the last of the goosefoot these rosettes of the wild lettuce held their color, and before the seedlings of the third year made their appearance they were again at work. Where *Chenopodium* had taken but a few weeks' advantage of *Amaranthus*, *Lactuca* profited by nearly half a year's handicap. At the beginning of the present season (1916) the wild lettuce shows very strong evidence that it is going to give the goosefoot a hard fight for its position as the dominant plant. It is the most eloquent sermon on preparedness that one can imagine.

One other factor thrusts itself into the situation. In the first paper note was made of the dominance of the tall ragweed, *Ambrosia trifida*, on a small area, the reverse slope of the levee at its extreme eastern end. During the second season this weed added to its original territory the river side of the same part of the embankment and at the beginning of the third season its seedlings are in evidence in advanced positions on other portions of the area. It may be that this invasion will cut off the feud between *Chenopodium* and *Lactuca* before they have a chance to carry the contest to a finish.

It is not likely that *Chenopodium* can hold its own against this army; *Ambrosia* has the same advantage of fecundity and early germination of seed. Whether *Lactuca* also will be swept down remains to be seen. It will be an interesting fight.

NEW SPECIES APPEARING DURING THE SEASON OF 1915.

Equisetum arvense.
Elymus robustus.
Sisymbrium officinale.
Polygonum aviculare.
Polygonum erectum.
Salsola Tragus.
Lepidium virginicum.
Potentilla monspeliensis.
Trifolium repens.
Verbena hastata.
Erigeron canadensis.
Anthemis Cotula.
Artemisia biennis.
Lactuca scariola.

BOTANICAL LABORATORY,
GRINNELL COLLEGE.

NOTES ON THE FLORA OF SITKA, ALASKA.

JACOB PETER ANDERSON.

INTRODUCTORY REMARKS.

On February 1, 1914, the writer began his duties in connection with the United States Agricultural Experiment Station at Sitka, Alaska. This made necessary a change in thesis subject and at the suggestion of Dr. Pammel, in whose department the major work was taken, the above subject was chosen.

The matter presented is based on collections, observations, and research during a period of two years. The facilities of the Experiment Station have been at the disposal of the writer, but these are quite limited, both as to literature and equipment. The region covered is that within easy walking or motor boat distance of the town of Sitka, but owing to the limited time for the purpose, this region has not been as thoroughly explored as it should be.

The Experiment Station has an herbarium containing several hundred specimens, but it is far from complete, except in the grasses, of which there is a good collection. The specimens from the vicinity of Sitka in said herbarium were collected by Professor C. C. Georgeson, head of the Alaska Experiment Station, and Drs. W. H. Evans and C. V. Piper of the Department of Agriculture at Washington. To these will be added the collections of the writer.

This thesis, as originally planned, was to consist of three parts: part one, to contain notes on the general aspect of the flora with special reference to ecology and economic plants; part two, to be a systematic list of the Pteridophytes and Spermatophytes; while part three was to deal with the fungus flora. Owing to inability to get determinations on some plants, part two is omitted for the present, but will be presented later, as will also notes on groups of parasitic fungi not taken up in detail in part three of the present paper.

In the preparation of these notes, special acknowledgements are due to Dr. L. H. Pammel of Iowa State College, at Ames,

under whose general supervision they have been prepared, to Mr. E. W. Merrill, of Sitka, who has kindly furnished the excellent series of photographs for the plates, many of which were taken expressly for this purpose, and to Dr. J. C. Arthur, of Lafayette, Indiana, who has identified the rust fungi.

THE FLORA IN GENERAL.

TOPOGRAPHY AND CLIMATE.

Sitka is located on the west, or seaward side of Baranoff Island in latitude 57° 3′ North, and longitude 135° 20′ West. It is built partly on gravelly soil, which is an old beach deposit, and partly on some low hills. In the rear of the town is a peat bog or Muskeg, beyond which are some low hills alternating with Muskeg until the base of the mountain is reached, which is less than a mile from the shore line. In most places in the region around Sitka, the distance from the sea to the base of the mountains is much less, as in many places the sea actually beats against the steep slopes of the mountain sides. Except some small areas at the mouths of streams and on the Muskeg the region is all heavily timbered up to about 2,500 feet elevation. The mountains rise to elevations of from 1,800 feet to more than 4,000 feet, with some peaks in the interior of the island about 5,000 feet in height. On some of the higher slopes small glaciers occur.

The shore line is very irregular and the sea in the vicinity is studded with islands. All except the smallest of these islands are forested.

The soil along the shore line consists of coarse gravel mixed with a black material composed mostly of decayed organic matter. Farther in we find some orange-colored soils supposed to be ancient volcanic ash from Mount Edgecombe. This of itself seems almost absolutely sterile to plant growth. This volcanic ash is covered with a layer of muck and peat, varying in thickness. Moss prevails nearly everywhere. At many places, especially on the steeper mountain slopes, there is scarcely anything that could be called soil.

The climate of Sitka is moist and equable. The precipitation averages about 85 inches per annum. Spring and summer are drier than autumn and winter. June is the driest month, with an average rainfall of 3.46 inches, while October is the wettest with 11.64 inches. The absolute minimum precipitation recorded at Sitka is .45 inches for July and the absolute maximum is 25.52 inches for September.

The average temperature is about 44° F. with only 23° difference between the averages for January and July. The average for the former is between 32° and 33° F., while for the latter month it is between 55° and 56° F. The absolute minimum ever recorded is —4° F., while the maximum is 87° F. There is but little sunshine. There may be weeks at a time when the sun shines every day, and again there may be weeks at a time when the sun is not seen at all. The actual sunshine for the year is probably not more than one-fourth the possible amount. During the growing season, the days are long. Near the summer solstice they are nearly eighteen hours long, the sun dipping only about 9½° below the horizon. Twilights are long.

HISTORICAL.

Sitka having been the Russian capital, as well as the American capital until 1906, it is but natural that more or less collecting of botanical material should have been done in the vicinity. The writer has not had the opportunity to examine into this phase of the subject, but a few facts have been gleaned incidentally. It appears that Henry Mertens of Lütke's expedition and H. G. Bongard[1] in 1832 described a number of species of plants from Sitka, C. B. Trinius describing the grasses. A. Kellogg visited Sitka in 1867.

Since the American occupation a number of collectors, including A. S. Hitchcock, H. C. Cowles and others, have visited Sitka, including the Harriman Alaska Expedition in 1899. Coville, Trelease and Saunders were of this expedition. The specimens in the Experiment Station herbarium were collected by C. V. Piper, W. H. Evans and C. C. Georgeson. A number of other collectors have been in the vicinity but the writer does not, at present, have definite information concerning them.

The following list of type species is incomplete. It is largely gleaned from Professor Piper's work, which includes only such species as are found in the state of Washington.

Agrostis aequivalvis	Picea sitchensis
Alnus sitchensis	Poa leptocoma
Arnica latifolia	Pteridium aquilinum pubescens
Bromus sitchensis	Pyrus diversifolia
Carex mertensii	Romanzoffia sitchensis
Carex sitchensis	Salix sitchensis
Cassiope mertensiana	Saxifraga bongardi
Cladothamnus pyrolaeflorus	Saxifraga mertensiana
Claytonia asarifolia	Scorzonella borealis
Corallorhiza mertensiana	Sorbus sitchensis
Elymus borealis	Trisetum cernuum
Festuca subulata	Tsuga mertensiana
Juncus mertensiana	Valeriana sitchensis
Lycopodium sitchense	Washingtonia purpurea

LIFE ZONES REPRESENTED.

There are three of the life zones represented. These are the Canadian, Hudsonian and Arctic-Alpine. Owing to the moist and equable conditions the limits of these zones are not well defined. While characteristic Canadian species, such as *Cornus Canadensis* and *Sanguisorba latifolia*, occur down to the sea level, we find a liberal admixture of species generally classed as Humid Transition. These, indeed, include some of our commonest species such as *Rubus spectabilis* and *Echinopanax horridum*. On the other hand, some of the characteristic Hudsonian plants are also found near sea level and growing freely in company with the Humid Transition and Canadian species. Among these may be mentioned *Nephrophyllidium crista-galli*. Even some Arctic-Alpine plants grow freely near sea level and among these may be mentioned *Empetrum nigrum*, which is the most abundant and characteristic of all the higher plants growing on the peat bogs or Muskeg.

The characteristics of the Arctic-Alpine zone appear at about 2,500 feet elevation. Plants properly belonging to the Hudsonian zone may reach an elevation of nearly 3,000 feet, while the Canadian species may reach 2,000 feet.

HABITAT GROUPS.

In considering the ecological aspects of the flora one finds that the plants can be segregated into a number of habitat groups. These are quite well defined, corresponding to their physical environment. Mixtures generally occur only in intermediate situations. The typical habitats are five, as follows: Littoral, Forest, Muskeg, Aquatic and Alpine. To these might be added a sixth—the weed habitat. These will now be taken up separately.

LITTORAL FLORA.

(PLATE XVI.)

Included in this group are the species that are found only, or most abundantly, on the sea beaches or their immediate vicinity. Some of these species thrive on rocks where there is scarcely any soil visible. Others occur on gravelly soil. Nearly all the soil found in the immediate vicinity of the sea is composed largely of coarse gravel, while in many places the shore is composed of bowlders or large rocks, in the crevices of which the plants may find some decayed matter and obtain a foothold. The folowing list includes the more typical plants found in this environment:

Ammodenia peploides
Atriplex littorale
Campanula sp.
Cochlearia officinalis
Draba sp.
Elymus mollis
Fritillaria camtschatcensis
Glaux maritima
Ligusticum scoticum
Pedicularis sp.
Plantago maritima
Polygonum paronychia
Polygonum viviparum
Potentilla villosa
Rhinanthus crista-galli
Sisyrinchium sp.
Triglochin sp.
Vicia gigantea

In addition to the group given above there are certain plants that, while not strictly littoral in their habits, are seldom found at any great distance from the sea and are not properly forest, marsh, or aquatic plants. These include several of the grasses, prominent among which are two species of Calamagrostis—C. aleutica and C. langsdorfii. Other plants of this habit are the following:

Achillea borealis
Anaphalis margaritacea
Aster peregrinus
Barbarea vulgaris
Conioselinum gmelini
Epilobium affine
Epilobium angustifolium
Geum macrophyllum
Lepidium sp.
Malus diversifolia
Mimulus langsdorfii
Monarda sp.
Pinus contorta
Potentilla anserina
Ranunculus sp.
Ranunculus tenellus
Rosa nutkana
Salix sitchensis
Sanguisorba latifolia
Sorbus sitchensis
Tissa marina
Veronica americana

FOREST FLORA

PLATES XVII TO XXI

The Forest flora is the most abundant, extensive, conspicuous, and important group of plants in southeastern Alaska. The jungle-like growth along the water courses is included under this head.

The forest itself is composed of but few species. The predominant tree, both in size and number, is the Sitka spruce ([illegible]). The second in importance is the Western Hemlock ([illegible]). The Alaska or Yellow Cedar ([illegible]) is quite abundant and two species of alder ([illegible] and A. [illegible]) are commonly met with along water courses. The Shore or Lodgepole pine (P[illegible]) is [illegible] the Muskeg near the shore where it is a shrub rather than a tree, but a few fair sized trees may be found back from the shore in the Muskeg. Above 2[illegible] feet the [illegible] is the only tree found and here it is generally low and bushy. It may come up to [illegible] feet, although the so-called timber line is about [illegible] feet, this being the limit of the spruce and of typical forest conditions.

Along the banks of streams near the shore and in the lower [illegible] is a dense jungle growth that is almost impenetrable (Plate XVIII). In this growth the Salmonberry [illegible] predominates, but such species as Devil's [illegible] with [illegible] and species of [illegible] are found.

The [illegible] of the forest is [illegible] by the undergrowth [illegible] by the fallen trees. These are [illegible]. They are covered with a dense [illegible] and they [illegible] lying there for many [illegible] the small growths on these [illegible] (Plate XX).

[illegible] the forest is the large amount of [illegible] hanging from the branches of the trees. This [illegible] of the Muskeg, where the [illegible] (Plate XXI) [illegible]

[illegible]

Other fair sized trees are [illegible] very little [illegible] found many [illegible] situations. The [illegible] as well as those [illegible] banks of water courses.

Aconitum delphinifolium
Actæa rubra arguta
Adiantum pedatum
Alnus oregona
Alnus sitchensis
Alsine borealis
Alsine crispa
Aquilegia formosa
Arabis lyrata occidentalis
Arabis intermedia
Arabis hirsuta
Arnica latifolia
Aruncus sylvester
Athyrium cyclosorum
Castilleja pallida
Castilleja parviflora
Chamæcyparis nootkatensis
Circæa alpina
Claytonia asarifolia
Claytonia sibirica
Coptis asplenifolia
Corallorhiza mertensiana
Cornus canadensis
Cytherea bulbosa
Echinopanax horridum
Epilobium latifolium
Erysimum cheiranthoides
Filix fragilis
Heracleum lanatum
Heuchera sp
Kruhsea streptopoides
Linnæa americana
Listera convallarioides
Listera cordata
Lycopodium selago
Lysichiton camtschatcense
Menziesia ferruginea
Moneses uniflora
Nabalus hastata
Oxyria digyna
Phegopteris dryopteris
Phegopteris polypodioides
Picea sitchensis
Polypodium vulgare
Polystichum braunii
Pteridium aquilinum pubescens
Pyrola secunda
Ribes bracteosum
Ribes laxiflorum
Romanzoffia [illegible]
Rubus pedatus
Rubus parviflorus
Rubus spectabilis
Salix sitchensis
Sambucus callicarpa
Saxifraga sp
Streptopus amplexifolius
Streptopus roseus
Streptopus [illegible]
Tiarella trifoliata
Tsuga heterophylla
Tsuga mertensiana
[illegible]
Urtica lyallii
Vaccinium cæspitosum
Vaccinium [illegible]
Vaccinium ovalifolium
Vaccinium parvifolium
Vaccinium [illegible]
Veratrum viride
Viburnum pauciflorum
Viola glabella
Viola langsdorfii
Washingtonia [illegible]
Washingtonia purpurea

MUSKEG FLORA.

(PLATE XXII.)

The term Muskeg, as here used, includes the formations variously called peat bogs, marsh and tundra. The last name, however, should not be used, as the Muskeg is quite different from the true Tundra which surrounds the Arctic Ocean.

This formation consists of peat covered by a layer of moss, mostly Sphagnum. The layer of living and dead, but still undecomposed moss is often a foot in thickness. The depth of the peat varies from a few inches to many feet. On the Muskeg north of the town of Sitka, a hole twelve feet in depth failed to reach the bottom. Scattered about are pools, the surface areas of which vary from a few square feet to several square rods. These pools are generally shallow, but their bottoms are exceedingly soft. In walking over even the firmer portions of the formations one mires a few inches.

Conspicuous features also include the tree growth and small stumps. Except along the edges and the water courses these trees seldom exceed five or six feet in height and are old and decrepit looking. *Pinus contorta* is the most abundant but *Tsuga heterophylla* is common and *Chamaecyparis nootkatensis* is occasional. There is a tendency for the formation to be built up around the base of these trees and especially around the stumps. This gives rise to slight elevations on which such forest species as *Cornus canadensis, Menzeisia ferruginea, Rubus pedatus,* and *Vaccinium vitis-idaea* are generally found.

The most abundant and characteristic plant of the Muskeg other than mosses is the Crowberry (*Empetrum nigrum*). It occurs from sea level to well above timber line. The Ericaceæ are well represented. *Andromeda polifolia, Kalmia glauca, Ledum groenlandicum, Vaccinium Oxycoccus* and *Vaccinium uliginosum* are common at the lower altitudes and *Chamaecystis procumbens* occurs locally. *Rubus chamaemorus* is one of the commonest species as is also the interesting little sundew, *Drosera rotundifolia.* A few species of sedges (*Carex spp.*) are found growing on the Muskeg, but the majority of species prefer the wet soil along the banks of streams or lakes. The cotton grass (*Eriophorum polystachyon*) is very conspicuous when in fruit.

Other plants found in this habitat are as follows:

Coptis trifolia
Dodecatheon sp.
Gentiana douglasiana
Juncus balticus
Juncoides campestre
Lycopodium annotinum
Lycopodium clavatum
Limnorchis dilatata
Limnorchis leucostachys
Parnassia palustris
Pinguicula villosa
Pinguicula vulgaris
Scirpus caespitosus
Tofieldia intermedia
Trientalis arctica

AQUATIC FLORA.

(PLATE XXIII.)

So far as the higher forms of plant life are concerned, this is the smallest division of the flora. Only one species has been noted as occurring in salt water and that is *Zostera marina*. The fresh water forms are a water lily (*Nymphaea polysepala*), two species of Potamogeton (*P. natans* and *P. heterophyllus*), *Callitriche verna*, and *Myriophyllum* sp., *Menyanthes trifolia*, *Comarum palustre*, *Sparganium* sp., and *Carex* spp. represent the semiaquatic species.

ALPINE FLORA.

Under this head are included all species that reach their maximum abundance at or above the ordinary line of timber, which in some cases may be somewhat less than 2,500 feet. Most of these belong to the Arctic-Alpine life zone, but some Hudsonian species are included. Their typical habitat is the Alpine meadows or the crevices of rocks. A very few extend down to sea level and several others are found occasionally between sea level and timber line. The soil at this elevation is largely of a peaty nature but drier and with less moss than the Muskeg. *Empetrum nigrum* is still very abundant and members of the Ericaceae are among the commonest forms. The following list includes the species of this group so far as observed.

Anemone narcissiflora
Arctoranthis cooleyæ
Artemisia borealis
Campanula sp.
Cassiope mertensiana
Cladothamnus pyrolæflorus
Cryptogramma acrostichoides
Epilobium sp.
Erigeron sp.
Gentiana sp.
Harrimanella stelleriana
Hieracium gracile
Lupinus nootkatensis unalaskensis
Lutkea pectinata
Lycopodium sitchensis
Nephrophyllidium crista-galli
Pedicularis sp.
Phyllodoce glanduliflora
Saxifraga spp.
Sieversia calthifolia
Tsuga mertensiana
Valeriana sitchensis

WEED FLORA.

Of all the weeds that occur in the area covered by this paper, there is one that stands out pre-eminent as causing more trouble than all others combined. That species is the common chickweed, *Alsine media*. The spurry (*Spergula arvensis*) probably would rank second in importance with sorrel (*Rumex acetosella*) third. The following list includes all the species that have as yet become important in this habitat group. It includes several introduced species as well as a few that are included in other lists.

Brassica arvensis
Bursa sp.
Cardamine sp.
Cerastium spp.
Epilobium angustifolium
Epilobium affine
Matricaria matricaroides
Mimulus langsdorfii
Monarda sp.
Montia fontana
Plantago major
Ranunculus repens
Rumex obtusifolius
Rumex occidentalis
Senecio vulgaris
Taraxacum officinale
Veronica americana
Veronica serpyllifolia

In addition to the foregoing, the following have been found, having been introduced with seed, packing, etc. They are, as yet, quite rare and of almost no importance from an economic standpoint. Some may in time become established.

Agrostemma githago
Anthemis cotula
Camelina sativa
Chenopodium album
Polygonum convolvulus
Polygonum pennsylvanicum
Saponaria Vaccaria
Sisymbrium officinale
Solanum nigrum
Sonchus asper
Vicia angustifolia

Mention might also be made of a parasite, *Razoumofskya douglasii tsugensis* (Plate XXIV), which causes much damage to the Western hemlock (*Tsuga heterophylla*). It attacks the branches causing them to enlarge and proliferate. Scarcely a host tree of any size is free from the parasite.

ECONOMIC PLANTS.

The economic plants of Alaska naturally arrange themselves in three groups: 1. Forest trees. 2. Grasses and forage plants. 3. Fruit-bearing plants. These will now be taken up in their order.

FOREST TREES.

Of all the plants native to the coast region of Alaska, the Sitka or Tideland spruce (*Picea sitchensis*) is by far the most valuable. It dominates the forest from Dixon Entrance to Prince Williams Sound. In the vicinity of Sitka it extends from sea level to 2,500 feet elevation. It attains large size. Logs, six feet in diameter, are sometimes received by the saw-mill at Sitka, but the average for the butt logs probably would be about four feet. Three of the larger standing trees near the Experiment Station, as measured by the writer, were 19 feet 2 inches, 18 feet 5 inches, and 16 feet 4 inches, respectively, in circumference about six feet from the base. It furnishes very good saw timber. The wood is light, soft, from fine to moderately coarse-grained. Its color is generally pale brown, often with a fine tinge of red. It is a long-lived species and the larger trees may be several centuries old. According to Sudworth[3] this species may attain a diameter of 12 feet and an age of probably 800 to 850 years. In addition to furnishing nearly all the native lumber used in the region of its occurrence there is a large probability that in course of time it will furnish the basis for a wood pulp industry.

In size and number of individuals the Western hemlock (*Tsuga heterophylla*) is second only to the Sitka spruce. It may dominate the forest locally. A mature tree which was already dead measured 14 feet 4 inches in circumference, but it was not possible to reach high enough to get clear of the buttressed trunk. Close by a typically mature tree measured 10 feet 9 inches in circumference. The wood is rather light, soft, fine-grained, pale yellowish brown with slightest tinge of red. The bark is claimed to contain a larger percentage of tannin than that of the Eastern hemlock (*Tsuga canadensis*). It is our most shade-enduring tree and the young plants may be found growing in the moss covering the earth, old trunks, rocks, etc.

Mountain or Black hemlock (*Tsuga mertensiana*) has comparatively little value. It is really an Alpine tree and reaches its greatest number of individuals at or above the limit reached by the other conifers. Above 2,500 feet, it is the only tree found and here it is usually low and sprawling. Well grown trees of moderate size occur in the forests, but the species becomes rare as one approaches sea level.

The third forest tree in point of importance is *Chamaecyparis nootkatensis,* locally called Yellow cedar, or simply cedar. It occurs from sea level up to above 2,000 feet. It is not so large as the Sitka spruce or Western hemlock, the largest trees observed by the writer being somewhat less than two feet in diameter. The wood is sulphur-yellow in color, very fine-grained, and comparatively heavy for its class. It is remarkably durable, works easily, and is valuable for interior finish.

Pinus contorta occurs mainly on the Muskeg where it is a stunted shrub. Well grown trees of moderate size occur in favorable locations, but they are infrequent. The wood is hard and resinous.

Red alder (*Alnus oregona*) is largely confined to the banks of water courses, where it may reach a diameter of one foot or more. The wood is pale reddish brown, light, and fine-grained. It is sought locally for fuel.

The Sitka alder (*Alnus sitchensis*) has a wider range of habitat than the Red alder, but does not grow so large.

GRASSES AND FORAGE PLANTS.

A large number of grasses are native to the region but there are three species that are outstanding from an economic point of view. These species are the Beach rye (*Elymus mollis*) and two species of Calamagrostis (*C. aleutica* and *C. langsdorfii*). The first is rather large and coarse but is claimed to make fine feed and silage. It occurs on the beaches and tide flats. The species of Calamagrostis attain a height of from three to six feet and are often called Alaska redtop.

Sedges are not generally so palatable or nutritious as grasses but may be used for feeding stock. Sedges are especially abundant on the borders of lakes (Plate XXIII).

Only one native legume is abundant enough to be of any value whatever as a forage plant. That one is *Vicia gigantea*. It occurs only near the sea.

FRUIT-BEARING PLANTS.

The majority of the fruit-bearing plants of Alaska belong to three genera, Ribes, Rubus, and Vaccinium. Several other groups are represented by one or two species.

Of the five species of Ribes native to Alaska, only two are found in the vicinity of Sitka. These are *R. bracteosum* and *R. laxiflorum*. *Ribes bracteosum* (Plate XXV) is very abundant and one of the most valuable of the native fruits. The bush has a tendency to be straggling, but the growth is very stout. The diameter of a season's growth often equals one-half inch. The racemes are long but the berries are rather scattered. In size it compares quite favorably with the garden black currant (*Ribes nigrum*) and has that same aroma, but to a more marked degree. The fruit is black, covered with a dense white bloom. All parts of the plants contain glands. Under favorable conditions it is very vigorous and the writer has found racemes 12¼ inches in length, while the leaves may reach an extreme length and width of about eight inches, a leaf of this size having been measured.

The fruit of the wild plant is utilized to a considerable extent. This species is quite promising for use in plant breeding. Crosses with *Ribes nigrum* show a vigorous growth the first year, with no appreciable difference between reciprocal crosses.

Ribes laxiflorum is a much more slender plant than *R. bracteosum* with a tendency for the canes to become prostrate and take root. It has a fetid odor while the taste of the fruit is rather sweetish and insipid. The clusters and berries are about the same size as that of the common garden currant (*Ribes rubrum*), but the fruit is black with whitish bloom and raised glands. It is of little value.

Of seven species of Rubus known to occur in Alaska five are found in the vicinity of Sitka. These will be taken up in order of their importance.

The Salmonberry (*Rubus spectabilis*) (Plate XXVI) forms dense jungles near the sea, along water courses, and in open forests. The canes are perennial, often attaining a diameter of one inch or more and a height of ten to twelve feet. Canes one inch in diameter often show five or six annual rings. Flowers are rose pink and come out very early. The fruit begins to ripen by the middle of June and continues until August, being at its height about July 1st. It is twice the size of ordinary raspberries, and consists of rather large, soft drupelets. The color varies from lemon yellow to dark red. It can be had in large quantities and is utilized to some extent. The flavor is different from that of any other berry. Crosses with the red raspberry (*R. strigosus*) have proven almost entirely sterile, as the pistils and stamens do not seem to develop properly.

The Thimbleberry (*Rubus parviflorus*) is only locally common. It is in cultivation for its large white flowers. The canes are imperfectly perennial, but are seldom more than four to five feet high. The fruit is depressed hemispheric, composed of numerous drupelets, red when ripe and of fair quality.

Rubus Chamaemorus, the Cloudberry, known among the Russians as Maruski, is common all over the Muskeg. It is herbaceous with creeping rootstock and erect branches. Each branch has one or two leaves and often a white flower. The fruit is the size of a large raspberry and consists of few but large drupelets which are amber to red when ripe. The natives are very fond of it and often gather it before it has thoroughly ripened. The quality is quite good.

Rubus stellatus resembles *R. chamaemorus* in habit, but prefers better drained locations and is not so abundant. The flower is pink. The red fruits are of good quality.

Rubus pedatus is a delicate creeping vine with five-foliate leaves found in abundance in forest and brushland. The fruit consists of from one to six rather large, distinct, red drupelets. While the quality is fair, it has but little value.

The strawberry (*Fragaria chiloensis*) though abundant in many places in the coast region of Alaska seems to occur around Sitka only as an escape from former cultivation. The fruit is quite large for a wild berry, and of excellent flavor.

The Crab apple (*Malus diversifolia*) (Plate XXVII) is a shrub or small tree which bears round to oblong fruit varying in size from that of a pea to three-fourths of an inch in length. In quality it is pleasantly, though rather strongly acid, without any trace of astringency. The fruit is used for making jelly and it also has value for the plant breeder.

The Vacciniaceæ are represented by not less than seven species, every one of which has some value.

Vaccinium ovalifolium, the earliest species to ripen, is very abundant and produces a fruit which averages about three-eighths of an inch in diameter, dark blue, with bloom and of good quality. It begins to ripen in June and continues through July. It is much used, especially for pies.

Vaccinium parvifolium (Plate XXVIII), the Huckleberry, is also very abundant, and reaches its maximum development in the dense shade near the base of the mountains. It is of a clear, bright, almost transparent red and of about the same size as the Early blueberry, although occasionally bushes bear much large fruits and the writer noted one the past season where the berries averaged better than one-half inch in diameter. It is of good quality and much used. It ripens in August and September.

Vaccinium chamissonis (Plate XXIX) is another Highbush blueberry that is abundant. It bears the largest fruit of any member of the genus, but the quality is not equal to that of the other species and many of the fruits are wormy; hence, it is not used to any great extent. The fruit is round to pyriform, purplish black, with scarcely any to very dense bloom. Berries five-eighths of an inch in diameter are sometimes found. The forms included under this head may form more than one species. The pyriform, black, bloomless fruit is quite distinct from the round to slightly depressed fruit with heavy bloom, but intermediate forms occur.

Vaccinium uliginosum is a low growing species common on the Muskeg. The blue berries are somewhat oblong in shape and ripen late. It is often gathered for use.

Vaccinium caespitosum (Plate XXX), is another low growing form and extends from sea level to above timber line. The fruit is somewhat smaller than that of the Highbush blueberries, but it excels them all in quality. While fairly common it is not abundant enough to be gathered economically.

Vaccinium vitis-idaea (Plate XXXI, figure 1), the Mountain cranberry, is our most valuable species of the group. It is dark red and is borne in small clusters at the end of the branches. It is an evergreen species with creeping stem and semi-erect branches. While the fruit is rather small it occurs in abundance and is used to a greater extent than any other native fruit. It is considered superior in quality to the cranberry of the States (*Vaccinium macrocarpon*) and was formerly shipped from Sitka in considerable quantities, but, of late years the native women have found other lines of work more profitable and the export of these berries has dwindled to a very small amount. It is often kept for months in a fresh state in cold water.

[illegible] (Plate XXXI, figure 2), the Swamp [illegible] of the cranberry grown in the States, [illegible] of the same quality, but smaller and variable in [illegible]. The vine is very delicate and often almost hidden in the [illegible] the lichens. It is quite common and used to a limited extent.

The [illegible]berry (E[illegible]) is abundant from sea level to Alpine heights [illegible] used as human food. It is important as a food [illegible] grouse and ptarmigan.

The High-bush Cranberry (V[illegible]) occurs rather sparingly. The [illegible] red fruit is of rather better quality than that of V. [illegible]. It is [illegible] of [illegible] value as a fruit [illegible] cultivated [illegible].

The Pigeon-berry ([illegible]) is an important food for birds [illegible] only as [illegible] mixture with [illegible] berries.

Several other [illegible] fruiting plants are known from Alaska [illegible] of [illegible].

DESCRIPTION OF PLATES

Plates are all from photographs by E. W. Merrill.

PLATE XVI.

Scene on a small island near Sitka. Near the rock just below the center may be seen some Blue bells (*Campanula* sp.). The white-flowered plant with finely divided leaves is *Achillea borealis;* the one with ternately decompound leaves is *Conioselinum gmelini;* the fern is *Polypodium vulgare;* the grass is *Hordeum boreale*, while the species that is so dominant at the top is Fireweed (*Epilobium angustifolium*). Some leaves of a native Currant (*Ribes bracteosum*) may be seen near the center.

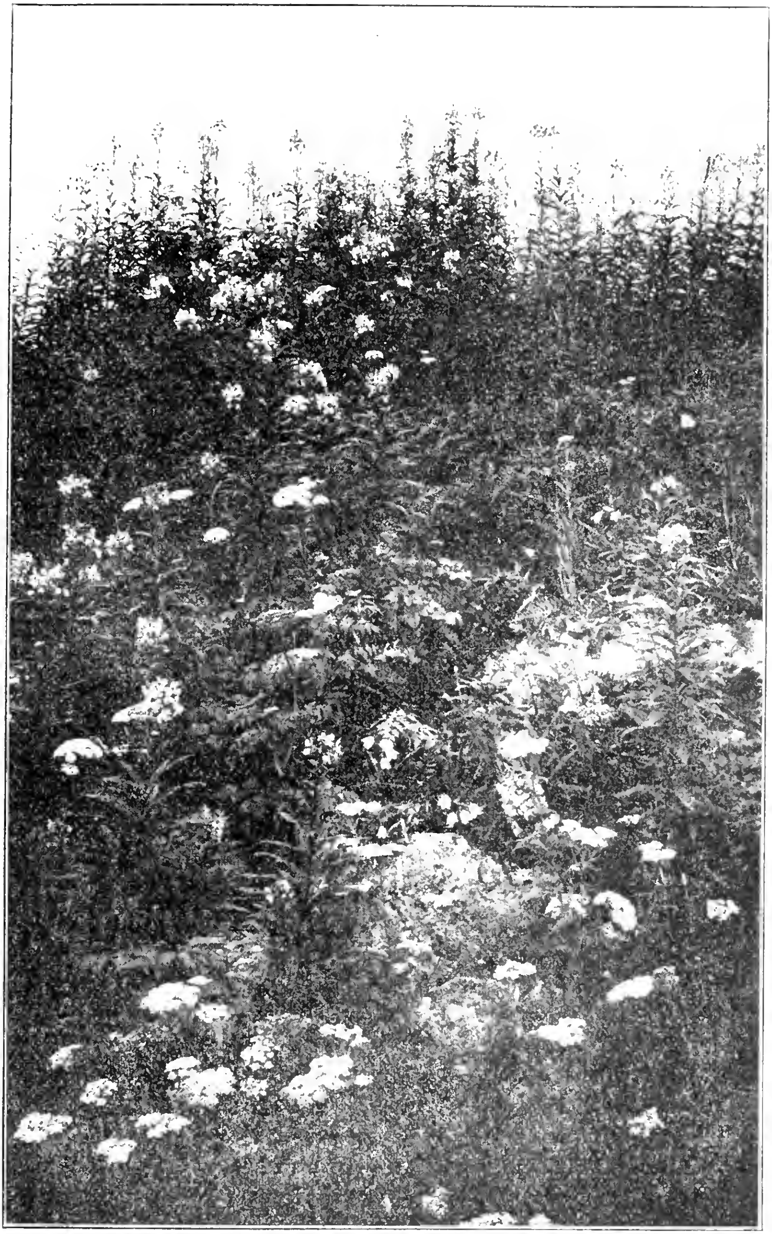


PLATE XVII.

View along a stream showing jungle-like growth along banks. This growth is composed mostly of Salmonberry (*Rubus spectabilis*). The large-leaved shrub is Devil's Club (*Echinopanax horridum*). Mixed in are Vacciniums and Currant (*Ribes bracteosum*), but these do not show in the plate. Note the Witches' brooms on the hemlock (*Tsuga heterophylla*), leaning out over the stream, also the moss and lichens hanging from the branches of this and the spruce just back of it. A young plant of Alder (*Alnus* sp.) appears in the lower left, while a plant of *Kruhsia streptopoides* is seen at the lower right corner.

PLATE XVIII.

Scene at 800 feet elevation showing dense growth of Vacciniums in the foreground. The two trees in the center (one of which is dead), are Hemlock (*Tsuga heterophylla*). Spruce (*Picea sitchensis*) may be seen in the background.

PLATE XIX.

Heavy timber at 800 feet elevation. The large trees in the foreground are Sitka spruce (*Picea sitchensis*). In the left background are Western hemlock (*Tsuga heterophylla*). The large-leaved plant is Skunk cabbage (*Lysichiton camtschatcense*). The shrubs are species of Vaccinium. *Cornus canadensis* may be seen at the base of the large tree in the foreground, and immediately to the left is a plant of a species of Streptopus.

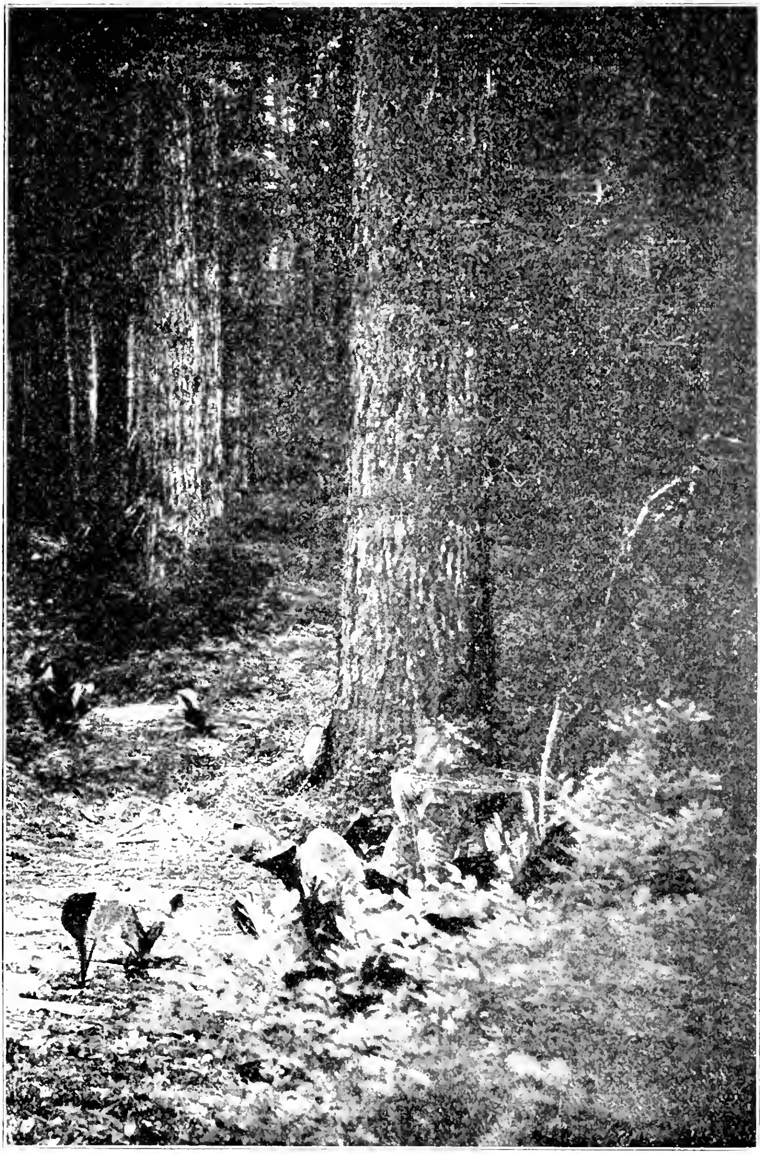


PLATE [illegible]

[illegible] covered with a large growth of moss and with [illegible] thirty years old growing on the [illegible] and the [illegible]

PLATE XXI.

An open formation at 1800 feet elevation. The most prominent species on the Muskeg here is Cotton grass (*Eriophorum polystachyon*). A dying cedar (*Chamaecyparis nootkatensis*) appears on the extreme right and other cedars, spruce, and hemlock are seen to be growing in association.

PLATE XXII.

View of Muskeg north of Sitka. Note the water holes and stunted trees. These trees are mostly Pine (*Pinus contorta*), but a few Hemlock (*Tsuga heterophylla*) are visible. The trailing bushes to the left of the central water hole are *Vaccinium uliginosum*. Clumps of Sedge (*Carex* spp.) and leaves of Cloudberry (*Rubus chamaemorus*) are also in evidence.

PLATE XXIII.

Scene on Swan Lake, north of Sitka. Note the Water lilies (*Nymphea polysepala*) to the left of which Potamogetons may be seen with *Menyanthes trifoliata* at extreme left. On opposite shore is a dense growth of Carex. The nest containing two eggs is that of the Red-Throated loon and is built on a floating mass of vegetation.

PLATE XXIV.

A branch of Western hemlock (*Tsuga heterophylla*) showing a severe infection of *Razoumofskya douglasii tsugensis*. This causes the branch to proliferate and form a Witches' broom.

PLATE XXV.

A branch of Currant (*Ribes bracteosum*), showing typical fruiting habit.

PLATE XXVI

Front and Training [illegible]

PLATE XXVII.

A branch showing fruit of native Crab apple (*Malus diversifolia*).

PLATE XXVIII.

Branches of Huckleberry (*Vaccinium parvifolium*)

PLATE XXIX.

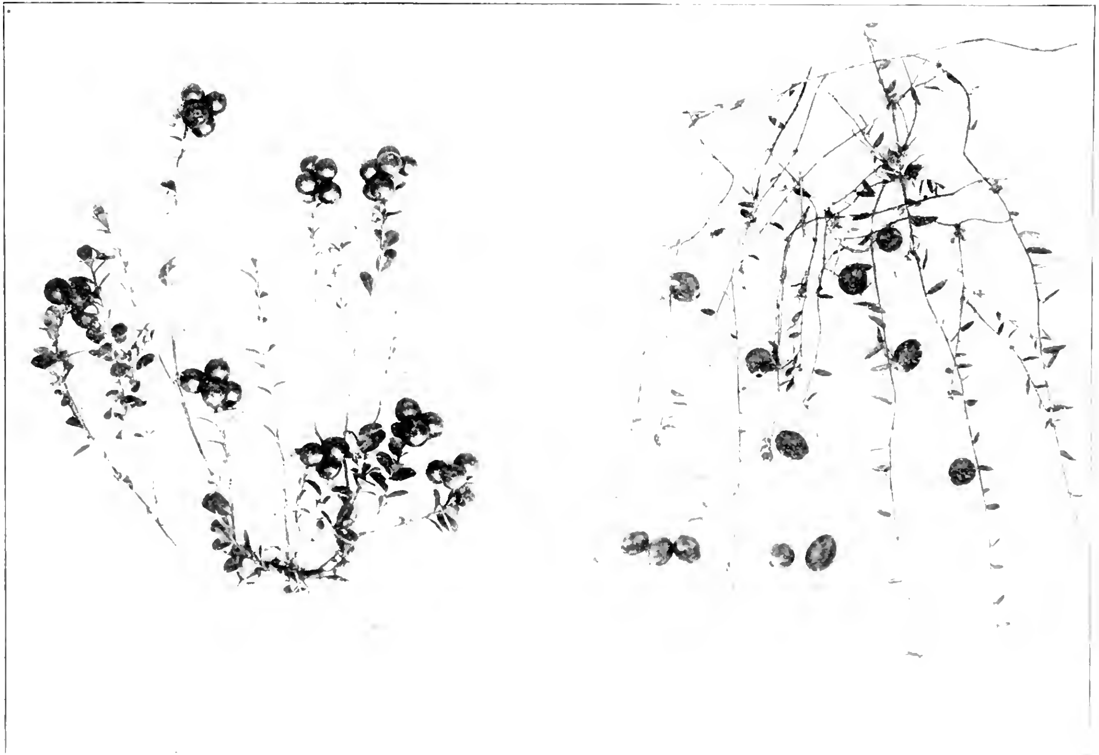
Branches of the Late blueberry (*Vaccinium chamissonis*).

PLATE XXX.

A Low bush blueberry (*Vaccinium caespitosum*).

PLATE XXXI.

Fig. 1.—The Mountain cranberry (*Vaccinium vitis-idaea*).
Fig. 2.—The Swamp cranberry (*Vaccinium Oxycoccus*).



THE FUNGUS FLORA.

Work on the fungus flora has been largely confined to parasitic forms or those appearing on particular hosts shortly after the death of the plant. Of the groups to which little attention has been paid, the Agaricaceæ should receive mention on account of their abundance in both species and individuals. Several species are gathered and used as food.

During the past two years, during which time the writer has been at Sitka, a collection of nearly 300 numbers of fungi has been made. In this collection imperfect forms and Pyrenomycetes greatly predominate. While many of the species are known, there are so many unidentified forms in most orders and families that it is deemed advisable, at this time, to consider only two groups—the Erysiphaceæ and the Uredinales—leaving the other groups until further identifications may be made, when it is hoped to present the same in considerable detail.

ERYSIPHACEÆ.

The Erysiphaceæ, commonly called Powdery mildews, are not so abundant as they are in many other localities. They were collected on only about fifteen different host plants, whereas the writer found them to occur on at least 186 hosts in the State of Iowa,[4] and Salmon[5] enumerates a host index of much more than 1,200 species.

In this list, and also the one that follows, on the Uredinales, the numbers in parentheses which follow the name of the host plant refer to the collection number.

Sphaerotheca humuli (DC.) Burr. Hop Mildew.

On *Epilobium affine* Bong. (72). On this host the mildew seems very destructive at times, and is quite widespread.

On *Fragaria chiloensis* (L.) Duchsne. What appears to be the conidial stage of this mildew is troublesome in the greenhouse on young plants which are hybrids of this species.

On *Fragaria platypetala* Rydb. This species also is affected in the greenhouse.

On *Ribes aureum* Pursh. (248). Only one slight infection observed on this cultivated species.

On *Ribes bracteosum* Dougl. (73 and 188). Not widespread but sometimes quite severe on this native currant. Some young hybrid seedlings of this species and the garden black currant (*R. nigrum*) became severely infected during the fall of 1915. It has not been observed on *R. nigrum*.

On *Ribes rubrum* L. (190). Does not seem to be severe on this host and there seems to be a great deal of difference in the resistance of the different varieties. Of the red currants grown at the Station, Perfection seems to be most susceptible.

On *Rubus spectabilis* Pursh. (187). Infection seems to be severe, but local.

Spaerotheca mors-uvae (Schw.) B. & C. Gooseberry mildew. this can be distinguished from the preceding by its dark, dense, felted mycelium. It is abundant on the fruits while *S. humuli* is mostly confined to the leaves, petioles and young stems.

On *Ribes lacustre* (Pers.) Poir. (74). During 1914 this species was very abundant and destructive, being found on berries, leaves and stems. Scarcely a fruit escaped its ravages. During 1915 it did but little damage. Two thorough sprayings with Bordeaux mixture helped to keep it in check. The host is native to Alaska, but does not occur near Sitka.

On *Ribes uva-crispa* L. (75). Very abundant and destructive on some varieties of the English gooseberry, while other varieties (e. g. Whitesmith) seem nearly immune.

Sphaerotheca pannosa (Wallr.) Lev. Rose mildew.

On *Rosa sp.* (180). This mildew is common and troublesome on many of the tea roses grown indoors.

Erysiphe graminis DC. Grass mildew. This species is not abundant, but the conidial stage occurs sparingly on a few grasses.

On *Agrostis exarata* Trin. (191).

Erysiphe sp. The conidial stage of a mildew has been collected on *Achillea borealis* Bong., and on *Ranunculus sp.* The former may be *E. cichoracearum*, DC., while the latter probably is *E. polygoni* DC.

Microsphaera alni (Wallr.) Wint. Alder mildew. This species does not seem to be common.

On *Alnus sitchensis* (Regel) Sarg. (213).

Uncinula salicis (DC.) Wint. The Willow mildew was collected at Skagway, by the writer, July 13, 1915, on *Populus trichocarpa* T. & G. (192), but has not been observed at Sitka.

UREDINALES.

This interesting group of obligate parasites is quite well represented, and most of the species are of more or less economic importance. Following the general usage the Roman numerals are used in the following notes to designate the three main stages in the life cycle of the rust. These are as follows: I—Aecia; II—uredinia; III—telia. Small bodies known as pycnia are generally found in association with the æcia and sometimes in association with the other forms. This stage is designated by O.

All the species here enumerated have been determined by Dr. J. C. Arthur of Lafayette, Indiana, who is recognized as one of the leading authorities on the group.

MELAMPSORACEÆ.

Melampsora biglowii Thum.

II—On *Salix sitchensis* Sanson. (193). The writer collected this at Skagway, July 13, 1915. It has not been observed at Sitka and probably does not occur, as the alternate host is Larix and this tree is not found in the vicinity.

Pucciniastrum myrtilli (Schum.) Arth.

II, III—On *Vaccinium caespitosum* Michx. (69).

II, III—On *Vaccinium ovalifolium* J. E. Smith. (196).

This rust seems to be rather infrequent.

Pucciniastrum pustulatum (Pers.) Diet.

II, III—On *Epilobium affine* Bong. (173), (271).

Common and quite destructive.

Melampsoropsis ledicola (Peck.) Arth.

II, III—On *Ledum groenlandicum* Oeder. (68).

Common, but only moderately destructive.

Melampsoropsis pyrolae (DC.) Arth.

II, III—On *Moneses uniflora* (L.) A. Gray. (70).

Common and sometimes locally destructive.

Hyalosora aspidiotis (Peck) Magn.

II, III—On *Phegopteris dryopteris* (L.) Fee. (67).

This is quite common.

Peridermium coloradense (Diet.) Arth.

I—On *Picea sitchensis* (Bong.) T. & M. (57).

This is very common around open places, but does not seem to be found in the denser forest. It is sometimes quite destructive to small trees, as it causes a loss of a large portion of the leaves. It is included under the family Melampsoraceæ as probably it is genetically connected with one of the foregoing species.

PUCCINIACEÆ.

Phragmidium occidentale Arth.

On *Rubus parviflorus* Nutt. (50 and 51).

On the Station grounds this rust is abundant enough to be decidedly injurious to the host.

Phragmidium rosae-acicularis Liro.

On *Rosa hemisphaerica* Herrm. (19). This host seems somewhat more susceptible than *R. rugosa* and its hybrids.

On *Rosa nutkana* Presl. (52 and 53). This is our native rose. It seems very susceptible.

On *Rosa rugosa* (267) and hybrids (195).

Xenodochus minor Arth.

On *Sanguisorba latifolia* (Hook.) Coville. (54, 113 and 202)

This rust is very common. All the forms occur. Dr. Arthur, in a letter to the writer, says concerning some material belonging to this species, which was sent to him September, 1915, "Your material gives the first collection of æcia belonging to *Xenodochus minor*, which has come to hand."

Gymnosporangium sorbi (Arth.) Kern.

O, I—On *Pyrus* (*Malus*) *diversifolia* Bong. (56).

This rust is common on the native crab apple and is sometimes injurious locally.

O, I—On *Sorbus sitchensis* Roem. (55). During 1914, this species was badly affected, but in 1915 it had suffered to such an extent from attacks of Entomosporium that but few leaves were left to be attacked by the rust.

Uromyces caryophyllinus (Schrank.) Wint.

II, III—On *Dianthus caryophyllus* L. (186). This rust developed rather sparingly on the common greenhouse carnation.

Puccinia acuminata Peck.

III—On *Cornus canadensis* L. (58). This rust forms dense, black, circular spots on the under surface of the leaf, 1 to 2 mm. in diameter. Infection is not general, but it is abundant in places.

Puccinia circaea Pers.

On *Circaea alpina* L. (203). Common wherever the host is found.

Puccinia epilobii-tetragoni (DC.) Wint.

I—On *Epilobium affine* Bong. (59). Common on young plants shortly after starting growth in the spring.

Puccinia grossulariae (Schum.) Lagerh. This species is by all odds our most abundant and destructive species of rust. Forms O and I occur on species of Ribes while forms II and III infect species of sedges belonging to the genus Carex. Of the fourteen species of Ribes growing on the Experiment station grounds in 1915, exactly one-half were affected. The different species differ very much in the degree of infection, as is noted under the remarks on each.

On *Ribes alpinum* (65). This host suffered a rather moderate infection, in both 1914 and 1915.

On *Ribes bracteosum* Dougl. (60). This species seems to suffer quite severely when exposed to infection from nearby sources of Carex, but plants growing in the forest away from sources of infection are nearly or entirely free.

On *Ribes lacustre* (Pers.) Poir. (61). This seems to be the most susceptible species of all. In 1914, the infection was severe indeed. In 1915, control measures were largely successful.

On *Ribes laxiflorum* Pursh. (63). The writer has observed plants of this species along the edge of the Muskeg where *Carex stygia* was abundant, so badly infected that they lost most of their leaves while a few rods away the infection was moderate to light.

On *Ribes oxycanthoides* L. (66). Varieties of gooseberry derived from the American species show moderate infection while some of its hybrids with the European gooseberry show light infection.

On *Ribes rubrum* L. (64). The common red currant seems to be rather lightly infected.

On *Ribes sanguineum* Pursh. (178). This species was planted on the station grounds in 1914. The first season it was scarcely infected at all, but in 1915 the infection was very severe.

On *Carex macrochaeta* C. A. Meyers. (251).

On *Carex mertensii* Prescott. (250).

On *Carex sitchensis* Prescott. (252). This and the two species above are moderately to rather severely infected.

On *Carex stygia* Fries. (197). This sedge is very abundant all over the Muskeg, and seems always to be heavily infected with the rust. From an economic point of view, it is by far the most important Carex host of the Puccinia under consideration, and from it most of the infection of the Ribes on and near the Experiment Station grounds probably takes place.

Puccinia poarum. Niessl.

II—On *Poa pratensis* L. (166). Not very common.

Puccinia pygmaea Erikss.

II—On *Calamagrostis aleutica,* Bong. (201 and 218). Frequent, but only a small portion of the host plants seem to become infected.

REFERENCES.

1. Mem. Acad. St. Petersb., *VI*, 2, 1832.
2. *Piper, C. V.*, Flora of the State of Washington: Cont. U. S. Nat'l Herb., *XI*, 1906.
3. *Sudworth, Geo. B.*, Forest Trees of the Pacific Slope. U. S. Dept. Agri., Forest Service, 1908, p. 93.
4. *Anderson, J. P.*, Iowa Erysiphaceæ: Proc. Iowa Acad. Sci., *XIV*, 1907.
5. *Salmon, E. S.*, A Monograph of the Erysiphaceæ: Mem. Torrey Bot. Club, *IX*, 1900.

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INSECT POLLINATION OF TIMBERLINE FLOWERS IN COLORADO.

L. A. KENOYER.

Nägeli attributes the fact that alpine flowers are more showy that those of the lowlands to the greater scarcity of insects on the mountain tops and the greater efforts thereby necessary on the part of flowers to secure their visits.

Bonnier states that insect visitors are quite rare on mountain flowers, and uses this as an argument to indicate that flower color plays a relatively unimportant roles in the attraction of insects.

Müller after extensive study of the subject states in his book, "The Fertilization of Alpine Flowers," that although there are long periods in which the weather of the mountain top does not favor the activities of insects, he is unable to convince himself that on the whole the flowers of the Alps are relatively less visited and crossed by insects than are those of the lowlands.

Schroeter in his consideration of the subject is inclined to deny Müller's proposition and to assert that in the Alps and on mountains in general the relative number of insects that effect cross pollination is less than in the lowlands.

Little investigation seems to have been made on the abundance and effectiveness of insect visits to flowers in our Rocky Mountain region. Mrs. Soth, who has written on the flora of Pike's Peak, states that insects are rare on mountain flowers, only an occasional bumble-bee being seen. Therefore I took advantage of a vacation in Colorado in the summer of 1915 to do a little work on alpine flowers and their visitors.

During the month from June 18 to July 18, I went ten times from my camp at Tolland, Colorado, to the parts of the continental divide above timber line, between James Peak and Corona. The insects collected on these trips were identified by Dr. T. D. A. Cockerell of the University of Colorado.

The most apparent recipients of the visits of bees are the mountain clovers. These plants sometimes occupy mountain areas almost to the exclusion of other plants. It seemed to me that in sunny weather when the wind is not too strong, bumble bees are as numerous on these clover fields of the mountains as one would expect to find them on a field of red clover at ordinary altitudes. Sometimes a dozen could be seen in a walk of a hundred feet.

Trifolium nanum is a dwarf plant coming into bloom in earliest summer. On it were found:

Bombus kirbyellus Curtis. Numerous.

Bombus edwardsii bifarius Cresson. Numerous.

Bombus (a small species).

Trifolium dasyphyllum is a larger plant and blooms a little later. Its visitors are

Bombus kirbyellus Curtis. Numerous.

Bombus edwardsii bifarius. Cresson.

Bombus appositus Cresson.

Bombus flavifrons Cresson.

Prosopis coloradensis Cockerell.

Osmia kenoyeri Cockerell (n sp.).

A blue butterfly.

Perhaps next in importance is *Polemonium confertum,* a plant contrasting in its erectness to the caespitose vegetation, so abundant on the mountains, and bearing a conspicuous cluster of dark purple blossoms with a musky odor. It is visited by

Bombus kirbyellus Curtis.

Halictus rasiphoræ Cresson.

also numerous flies, among which are species of Eristalis and the Anthomyineæ.

Mertensia bakeri is another bee flower. Its guests include

Bombus edwardsii bifarius Cresson.

Bombus flavifrons Cresson.

Eristalis sp. among the flies.

Silene acaulis, the well-known Mountain Pink, was visited by

Bombus edwardsii bifarius Cresson.

A small gray bee.

Melittia (a butterfly).

A moth.

H. Müller in the European Alps found this plant visited prevailingly by Lepidoptera. L. H. Pammel found Lepidoptera abundant on the same plant in the Medicine Bow region of our Rockies.

On *Primula angustifolia* was seen a Bombus; on *Frasera stenosepala*, rare above timber line, was found

Halictus rasiphoræ Cresson.

Halictus regis Cockerell (n. sp.).

On *Castilleja sulphurea* was a *Bombus kirbyellus* Curtis, which had just visited *Trifolium dasyphyllum*; on *Alsimopsis obtusiloba* was apparently a species of the little red parasite, Sphecodes; on *Heuchera parvifolia* a small bee; on *Phlox caespitosa* a small bee; on *Sieversia turbinata*, a species of Prosopis; on *Arenaria fendleri*, *Prosopis coloradensis* Cockerell; on *Thlaspi coloradense*, *Halictus sisymbrii* Cockerell; on *Erigeron pinnatisectus*, *Prosopis coloradensis* Cockerell and *Prosopis personatella* Cockerell (n. sp.).

The plant most conspicuous and visited by the greatest number of insects is the sunflower-like *Rydbergia grandiflora*. The only bee noticed on it was a green form, probably Angocholora, seen three times. There were numerous butterflies, among them Melittia, Lycaena, and a white form. Among the very many flies are Syrphidæ and Anthomyineæ. Butterflies seem to take a greater fancy to it than to any other plant of the region.

The plant which seemed most noticed by flies is the very common *Sieversia turbinata*. Among these ever-present guests are Anthomyineæ and Empididæ. Ants also are found here.

There are several other flowers that seem open to the approaches of flies and ants. The most important are *Dryas octopetala*, *Potentilla uniflora*, *Lloydia serotina*, *Micranthes rhomboidea*, Caltha, *Polygonum bistortoides*, *Oreoxis alpina*, *Arenaria fendleri*, *Eriysimum wheeleri*, *Ranunculus adoneus* and *Heuchera parvifolia*. Some of these flowers are very conspicuous and others but slightly so, but all agree in having the nectar practically exposed and in the reach of all comers. The Anthomyineæ are easily the prevailing forms among the flies, although Syrphidæ are quite common. Müller finds Caltha, Dryas, the Potentillas and the Ranunculi visited mainly by flies in the Alps.

A bumble bee, probably *Bombus edwardsii bifarius*, was seen entering a hole among the rocks above timber line, doubtless leading to its nest. A male specimen of *Osimia abnormis* Cresson, was taken from the rocks where it was apparently seeking shelter from the wind. I desired to learn the extent to which the alpine flowers are dependent upon insects for their pollination, so I stretched cheese cloth and mosquito netting over wire domes, which by means of stakes driven into the ground I attached securely over plants just prior to their blooming season.

My stay was too brief to permit me to obtain definite results in all cases, but I can report as follows:

1—No seeds on covered plants, seeds on uncovered: *Polemonium confertum, Trifolium dasyphyllum, Silene acaulis.*

2—Practically as many seeds on covered as on uncovered plants: *Ranunculus inamoenus, Oreoxis alpina, Sieversia turbinata, Erysimum wheeleri.*

It is worthy of notice that the flowers that require insect visits for pollination are mainly the bee flowers, while those that get along without them are principally the fly flowers. Perhaps the real reason for this difference is the relative arrangement of the floral parts. The bee-flowers are long-tubed and are apt to have stamens and pistils relatively remote from one another. On the whole the flowers of the two groups are about equal in showiness.

Of course when the wind is quite strong or when rain or snow is falling or the clouds are dense there is a scarcity of insects in sight. But selecting comparable weather and excluding the honey bee, which does not live at high altitudes, it seems to me that the flowers above timberline are as much visited by insects as are those of lower altitudes, and I have no reason to suppose that they are any less dependent for pollination upon their insect visitors.

Dr. L. H. Pammel, who has given some attention to Alpine flowers in various sections of the Rocky Mountain region, thinks that insects are practically as abundant on Alpine as on lowland flowers.

I must express my appreciation to Dr. Francis Ramaley for extending to me the courtesies of the Colorado University Laboratory at Tolland.

LITERATURE CITED.

Nageli, C. Von, Entstehung und Begriff der naturhistorischen Art, München, 1865.

Bonnier, Gaston, Les Nectaires. Annales Des Sciences Naturelles (Botanique), Paris, *VIII*, 1879.

Müller, Hermann, Die Alpenblumen, ihre Befruchtung durch Insecten und ihre Anpassungen an dieselben, Leipzig, 1881.

Schröter, C., Das Pflanzenleben der Alpen, Zurich, 1904.

INSECT POLLINATION OF *FRASERA STENOSEPALA*.

L. A. KENOYER.

One of the largest of herbaceous plants growing at Tolland, Colorado, 9,000 feet above sea level, is the green gentian, *Frascra stenosepala*. A rosette of basal leaves gives rise to a coarse stalk, three to four feet high, with whorls of large leaves and a leafy panicle of rather large flowers of a light green color. Singularly the color is about as inconspicuous as can be imagined. The flowers are rendered rather noticeable by the size and isolation of the plants, but much less so by color. Yet it appeared to surpass all other flowers of the region in the number and variety of insect visitors. The yellow *Thermopsis divaricata* or mountain pea is abundant where Frasera grows. It has a color that renders it visible at a much greater distance than is Frasera, yet it is much less frequently visited by insects.

A casual study of the Frasera blossom shows, as its principal attraction to bees, two trough-like nectaries which lie on the inner face of the petal, extending almost half its length, and protected against the weather and against small insects by a fringe of hairs on either side of each trough. Bumble bees that visit the flower pass successively to its nectaries, passing the tongue through each. In so doing they rub against the stamens and the pistils in such a way that they could easily effect pollination.

At a number of times during the latter part of June and the early part of July, 1915, insects were captured from the blossoms. Determinations made through the courtesy of Dr. T. D. A. Cockerell of the University of Colorado, show them to be as follows:

Bombus edwardsii bifarius Cresson.

Bombus edwardsii kenoyeri Cockerell (n. var.)

Bombus rufocinctus astragali Cockerell.

Bombus appositus Cresson.

Psithrus insularis Smith.

Psithyrus latitarsus Morrill.

Megachile wootoni caligaster Cockerell.

Monumetha albifrons Kirby.

Colletes salicola geranii Cockerell.

Colletes kincaidi Cockerell.

Colletes—two unidentified species.

Chelynia nitida Cresson.

Andrena lewisii Cockerell.

Halictus inconditus Cockerell (n. sp.)

Halictus fraseræ Cockerell (n. sp.)

Halictus rasiphoræ Cockerell.

Halictus regis Cockerell (n. sp.)

Odynerus sp.

The latter two species of Halictus were collected from a dwarf plant, about eight inches high, just above timber line. All of the others are from larger plants at Tolland, which is one or two thousand feet below timber line.

A plant was covered with cheese cloth to determine whether self pollination could occur without insects. Observations on this plant and on three average untreated ones were taken a month later by Miss Helen Leonard. Unfortunately, the covered plant had become badly affected by aphids before the seeds set.

The following is the numerical result:

	TOTAL NO. OF FLOWERS	NO. UN-POLLINATED	PER CENT UN-POLLINATED
1. Covered plant	145	76	52
2. Plant not covered.......	330	10	3
3. Plant not covered.......	547	116	21
4. Plant not covered.......	368	81	22

The evidence points pretty clearly to the fact that, while pollination may occur without bees, it is much more effectively done when their visits are permitted.

DEPARTMENT OF BOTANY,
IOWA STATE COLLEGE.

NOTES ON THE WEEDS OF CALIFORNIA.

L. H. PAMMEL.

During the month of August, 1915, the writer and Mrs. Pammel spent a month visiting California. Our journey took us over the Western Pacific railroad from Salt Lake City. This railway passes over the Sierra divide and down the Feather river canyon, down the Yuba and Sacramento flood plains, thence into San Francisco. At several points along the line stops were made and some collecting was done. From San Francisco we went over the Southern Pacific to Big Trees, Santa Cruz, Monterey, Santa Barbara and Los Angeles—from the latter point over the Santa Fe to San Diego and return up to San Bernardino. At each of these places we stopped and had an opportunity to collect plants and make notes on the more common weeds.

Dr. Hilgard some years ago published some notes on the weeds of California[1]. He states that the broad fact that first strikes the new-comer in California is that a number of plants that are objects of careful culture east of the Rocky Mountains as well as in Europe, and that when deprived of protection soon succumb, in California thrive and are persistent weeds, and many weeds which are conspicuous on the Atlantic coast are absent in California. He mentions the beet, celery, radish and carrot as conspicuous weeds. Some of the smartweeds so common in the east do not maintain themselves in California. Occasionally one finds the Pennsylvania smartweed (*Polygonum Pennsylvanicum*) in low grounds. The *Spergula arvensis* is common in moist places along the coast. The *Erodium cicutarium* and *E. moschatum* are common plants everywhere in California. The *Oxalis corniculata* is rather common in places. In some places there is an abundance of *Glycyrrhiza lepidota*. Fennel (*Anethum graveolens*) is common in many places and so is the *Conium maculatum* and the caraway (*Carum carui*). Here and there in the vicinity of San Francisco one may observe the Teasel (*Dipsacus*). The *Madia sativa* is quite widely distributed and generally is regarded as a troublesome weed.

[1]Garden and Forest [illegible]: 316, 328, 371, 424, 478, 494.

It secretes a substance that is decidedly objectionable. The *Amsickia intermedia* and *A. lycopsoides* is most troublesome. The aspect of a California field is entirely different than an Iowa or an Illinois field. Broad acres are covered with the Yellow Knapweed or Tocalote of the Mexicans (*Centaurea melitensis*) and *C. solstitialis* are among the most troublesome weeds of the meadows. In the Sacramento Valley and in the foothills and valleys there is an abundance of the California poppy (*Eschscholtzia californica*). The roadsides are covered with one of the numerous species of Tarweed (*Hemizonia luzulaefolia*). The great Star Thistle (*Silybum marianum*) and annual grasses like Wild barley (*Hordeum murinum*) cover wide stretches of the fertile fields. The two species of Prickly lettuce (*Lactuca Scariola* and the variety *integrata*) are common everywhere in waste places. Certain weeds like the Greater Ragweed (*Ambrosia trifida*) are missed entirely. The Foxtails (*Setaria glauca* and *S. viridis*) are not common as with us. Hilgard notes that *S. glauca* is a formidable weed in the foothills of the Sierras and that *Bromus mollis* is a formidable weed. The Russian thistle (*Salsola Kali* var. *tenuifolia*) is a common weed. White sweet clover (*Melilotus alba*) is common in places. The Black medick (*Medicago lupulina*) and the Bur clover (*Medicago denticulata*) and Wild oats (*Avena fatua*) are common weeds.

In the Feather river canyon at an altitude of 4,000 feet there is comparatively little land that can be cultivated. In fields and waste places in the vicinity of Portola the writer observed *Lactuca scariola* and the var. *integrata*, Mayweed (*Anthemis Cotula*), *Eschscholtzia californica* var. *tenuifolia, Sisymbrium altissimum, Sisymbrium* sp., *Polygonum aviculare, Hordeum jubatum, Sitanion elymoides, Achillea Millefolium, Gayophytum* sp., *Hemizonia* sp., *Pteris aquilina, Rumex Acetosella* and *Wyethia*. This sunflower or rosin weed (*Wyethia*) of the open meadows in the mountains occupies waste places in streets and along roadsides.

Near Belden, at an altitude of about 2,800 feet, the following weedy plants were observed: *Erigeron canadense,* Common mullein (*Verbascum Thapsus*), *Anthemis Cotula,* Cow herb (*Saponaria Vaccaria*), Mexican tea (*Chenopodium ambrosioides*), Russian thistle (*Salsola Kali* var. *tenuifolia*), (*Lactuca*

Scariola and the var. *integrata*), Sour Dock (*Rumex crispus*), Dooryard Knotweed (*Polygonum aviculare*), Tumbling Mustard (*Sisymbrium altissimum*), the Iowa Tumbleweed (*Amaranthus graecizans*), Shepherd's Purse (*Capsella Bursa-pastoris*).

The following weeds are abundant in the vicinity of Yuba City in the Yuba bottoms: The European Morning glory (*Convolvulus arvensis*), Prickly lettuce (*Lettuce Scariola* and the var. *integrata*), Johnson grass (*Sorghum halepense*) a very pernicious weed. Bermuda grass (*Cynodon Dactylon*), Lamb's quarters (*Chenopodium album*) and our Iowa pigweed (*Amaranthus retroflexus*) were abundant. The Spiny clotbur (*Xanthium spinosum*) and a species of Croton were common in fields. The roadsides also contained an abundance of Sunflower (*Helianthus annuus* and *H. lenticularis*). The Russian thistle, as in other parts of central and northern California, was abundant. The Yellow Starflower or Knapweed (*Centaurea melitensis*) occurred not only along the roadsides but the harvested grain fields were yellow with the flowers of this species. The *Polygonum aviculare* and *Lippia* sp. were common in yards. *Chenopodium ambrosioides, Echinochloa crusgalli, Rumex crispus, Verbascum Thapsus, Marrubium vulgare, Sisymbrium altissimum, Avena fatua, Erigeron canadense, Cichorium Intybus, Melilotus alba, Eschscholtzia californica* and *Grindelia* sp. were all common in fields and along roadsides.

In the Bay region, Oakland, San Francisco and other points weeds of the mustard family (*Cruciferae*) are common. The common Mustard (*Brassica campestris*), Hedge Mustard (*Sisymbrium officinale*), the Common radish (*Raphanus sativus*) and the Jointed Charlock (*R. Raphanistrum*) are two of the most common weeds of the Bay region. The California poppy (*Eschscholtzia californica*) is common, as well as the Sow thistle (*Sonchus asper*); the Bull thistle (*Cirsium lanceolatum*) and the May weed (*Anthemis Cotula*) occur sparingly. Gray observed in 1876[2] "sparingly found along roadsides; introduced but not yet common." Dill (*Anethum graveolens*) is common in Oakland. Evidently it was not established in California in 1876 as it is not mentioned by Brewer and Watson.[3] Celery (*Apium graveolens*) in 1876 was reported by the same authors as occurring from Santa Barbara to San Diego in salt marshes.

[2]Botany of California *1*: 401.
[3]Bot. of California *1*: 252.

Doctor Hilgard in 1891 stated it was common in the Bay region. It is not a common weed except, perhaps, in the salt marshes. Hemlock (*Conium maculatum*) was a sparingly introduced plant in waste places about cities in 1876. It is common in many places now in the vicinity of Oakland and elsewhere. Other weeds in this Bay region are Hollyhock (*Althoea rosea*), Beet (*Beta vulgaris*), Buckhorn (*Plantago lanceolata*), Jimson weed (*Datura Tatula*), *Verbascum Thapsus, Lactuca Scariola* and the variety *integrata*, Carrot (*Daucus Carota*), Wild barley (*Hordeum murinum* and *Hordeum nodosum*). The *H. murinum* was evidently not common in California in 1876. *Melilotus alba, Medicago denticulata* and *M. lupulina* were common in the region as well as the *Silybum marianum*.

Santa Cruz in the Monterey Bay region on the coast, south of San Francisco and west of the coast range contains many of the weeds found further north. The roadsides in places are lined with tarweed (*Hemizonia Sp.*) and Rosin weed (*Grindelia*), Radish (*Raphanus sativus*), jointed charlock (*R. Raphanistrum*), Russian thistle (*Salsola Kali* var. *tenuifolia*), *Medicago lupulina, M. denticulata, Melilotus indica*. The latter occurs abundantly and is a troublesome weed. The Alfilaria (*Erodium cicutarium*) is an abundant weed on roadsides and in fields. Sometimes it is used most effectively to cover waste places. *Brassica campestris* and *Rumex crispus, Hordeum murinum* and *Centaurea melitensis* are quite as common as in the Sacramento Valley, Pacific Grove and the Monterey peninsula on the other side of the Bay. In one place the dodder (*Cuscuta Epithymum*) has practically destroyed alfalfa.

In the city of Pacific Grove and outside I saw an abundance of the Poison Hemlock (*Conium maculatum*) and *Hordeum murinum* everywhere on the sand dunes. The *Polygonum aviculare* and occasionally some *P. convolvulus* are present in grain fields to the east of Pacific Grove. At Salinas where some of the soil is more or less salty I saw an abundance of caltrop (*Tribulus terrestris*). The *Hemizonia luzulaefolia* as elsewhere in the valley is a troublesome weed. The odor is most objectionable; stock do not forage on the weed. At Santa Barbara, further south on the coast, one finds again the tarweeds in abundance. I noticed two species of *Hemizonia* abundant. In some cases fields were fairly yellow with it. The *Eschscholtzia californica* was common and the *Lippia* covered great stretches and here it is used quite effectively to cover banks and waste places.

In Los Angeles, south of Santa Barbara, I observed *Erigeron canadensis, Datura Tatula* and a great deal of *D. meteloides, Franseria* sp., *Lactuca Scariola, Melilotus alba, Xanthium canadense,* Radish (*Raphanus sativus*), Iowa Tumbleweed (*Amaranthus graecizans*), Pigweed (*A. retroflexus*), *Convolvulus arvensis, Brassica campestris, Sorghum halepense, Marrubium vulgare, Urtica holosericea, Ricinus communis, Nicotiana glauca, Solanum nigrum, Helianthus annuus,* Dill (*Anethum graveolens*).

The San Diego region in the extreme southern portion of California is much more arid than Los Angeles, where irrigation is practiced. A number of northern weeds occur. We note, however, that in waste places, there is an abundance of *Nicotiana glauca* and *N. attenuata* and some *Ricinus communis, Digitaria sanguinalis* and *Setaria glauca* though *Digitaria* and *Setaria* are nowhere abundant in California. *Erigeron canadense, Xanthium canadense, Amaranthus graecizans, Chenopodium album, Avena fatua, Helianthus annuus, Polygonum aviculare, Hordeum murinum, Plantago lanceolata, Cosmos bipinnatus, Cucurbita foetidissima* are some of the other weeds which occur in southern California. There is a great deal of *Datura meteloides* as well.

A list of weedy plants might be greatly extended. The outstanding fact is that many of the weeds like *Salsola, Centaurea, Raphanus, Beta, Daucus, Datura, Chenopodium* and *Hordeum* are European, while a relatively small number are of tropical origin like *Amaranthus, Nicotiana, Ricinus* and *Cosmos.* The conspicuous native weeds are *Hemizonia, Gayophytum, Helianthus* and *Croton.* It is a striking fact that so few of the perennial native plants have become weeds. The seeds of most of the weeds germinate during the rainy season and rapidly mature their seeds, leaving the landscape seer and brown. The yellow composites like *Hemizonia, Grindelia* are in strong contrast to the dead annual grasses that mark the California landscape in August.

SOME NOTES ON CALIFORNIA FOREST FLORA.

L. H. PAMMEL.

Not much that is new can be presented on the forest flora of the state of California. The interesting forest flora of California has been worked over most carefully by a large number of eminent botanists; of the later contributions we may mention a few of the more recent: namely, the work of Willis Linn Jepson, "The Trees of California"[1] and by the same author "The Silva of California,"[2] published in 1914, which is the most complete and exhaustive treatise on trees of any given local region; the work of Sudworth, "Forest Trees of the Pacific Slope;"[3] the work of Sargent, "Manual of the Forest Trees of North America Exclusive of Mexico"[4] and his monumental work, "The Silva of North America" in fourteen volumes, and Britton's "North American Trees."[5]

Many botanists have, of course, contributed to our knowledge of the trees of California. Of the earlier botanists and explorers mention may be made of Kellogg, Brewer, Parry, Douglas, Nuttall, Fremont, Bolander, Watson, Gray and Torrey. Of the later botanists mention may be made of H. M. Hall, W. R. Dudley, Baker, Green, S. B. Parish, Heller, Macbride, Cleveland and Orcutt.

Our visit during the summer of 1915 included stops at Portola and Belden in the Feather river canyon, at Yuba City, the Bay region around San Francisco, Big Trees region near Santa Cruz and Monterey, Santa Barbara, Los Angeles, San Diego and San Bernardino. Representative types of trees were collected and herbarium material prepared.

Those who are familiar with the topography of California know that there are two rugged chains of mountains, the Sierra Nevada in the eastern part of the state and the Coast Ranges near the coast. Between these ranges a "Great Valley" as it is called contains the Sacramento Valley, the northerly valley in which the Feather, Yuba and other rivers join the Sacra-

[1]228 pp. figs. 115. Cunningham, Curtiss and Welch, 1909.
[2]Memoirs of the University of California, 2: 1-480, 85 *pl.*, 10 *figs.*, 3 *maps.*
[3]U. S. Department of Agriculture, Forest Service, 441 pp. figs., October 1, 1908.
[4]846 pp.; 642 *figs.*, 1 *map.*
[5]N. L. Britton and John A. Schafer, 894 pp.; 781 *figs.*

mento. The valley to the south is known as the San Joaquin within which the river of that name receives the waters of many small streams. Jepson calls attention to the fact that the north coast ranges differ in a marked degree from the south coast ranges. The former are marked by the development of the redwood belt, the tan oak and Douglas fir. These forest tree species are some of the marked features of this region. This region, too, has a large rainfall. Jepson gives the normal seasonal rainfall as 45.59 inches with the highest recorded temperature as 84° above freezing and the lowest as 20° above freezing. These data are for Eureka. In the southwest ranges, the region lying below San Francisco is characterized by long, dry, rainless summers and a low rainfall. In the Santa Cruz mountains facing the ocean an abundance of redwood, tan oak, sycamore, Douglas fir, madrona and maple grows. The Monterey bay region contains an interesting peninsula with a number of conifers of restricted ranges. Jepson terms the region an "aboreal island." Here are found the Monterey pine (*Pinus radiata*), Bishop's Pine (*Pinus muricata*), Monterey cypress (*Cupressus macrocarpa*) and the Gowen cypress (*Cupressus goveniana*). In the moister valleys of the coast range near Los Angeles such deciduous trees as the large leaved maple, sycamore, alder, maul oak and Douglas fir occur.

In the San Diego district the valleys contain the cottonwood (*Populus Fremontii*), the arroyo willow (*Salix lasiolepis*) and the black willow (*Salix nigra*). On the coast north of San Diego about twenty-six miles, at a point known as the Torrey pine hill, is the Torrey pine, of very restricted distribution.

The forest province designated as the Sierra Nevada includes the area in eastern California from the base of the San Joaquin and Sacramento valleys and the east slope of the range. The Lake Tahoe district and the low foothills approaching the Feather river divide belong to this area. The annual rainfall in the foothills is low and the tree vegetation is small. The most characteristic tree at the mouth of the Feather river canyon is the digger pine (*Pinus sabiniana*) which is associated with the blue oak (*Quercus Douglasii*). This is followed further by the belt of yellow pine (*Pinus ponderosa*) and incense cedar (*Libocedrus decurrens*). Then come the Jeffrey Pine (*Pinus ponderosa*, var. *Jeffreyi*) and the Silver Pine (*Pinus monticola*). Professor Jepson gives the precipitation in inches for Blue canyon for the years 1907-08 as 49.05 inches; however, in 1906-07 the precipitation was 100.47 inches. Blue canyon is in the Yellow pine belt and south of the Feather river canyon.

The mountains of south California, such as the San Bernardino, blend with those of the coast ranges. The mountains about San Bernardino contain the yellow pine, sugar pine and large fruited fir (*Pseudotsuga macrocarpa*), the maple (*Acer macrophyllum*), alder (*Alnus rhombifolia*), sycamore (*Platanus racemosa*), California black oak (*Quercus Kelloggii*) and maul oak (*Q. chrysolepis*).

PINACEÆ Pine Family.

The following conifers of the genus *Pinus* were observed. Sugar Pine (*Pinus Lambertiana* Dougl.). This is the largest and finest of the white pines, with pendulous cones 12 to 18 inches long. It occurs on the high points about Belden and Portola. The writer saw some fine specimens in the mountains of San Bernardino, near the summer resort called Skylands.

Western White Pine or Silver Pine (*Pinus monticola* Don.) is common in some parts of the Sierras. Jepson gives the altitude from 5,500 to 8,000 feet above sea. It was found near the Western Pacific Railroad Station of Belden, which is less than 4,000 feet above sea. It is, however, scattered through the forests, with only a few trees in a place at this point.

Yellow Pine (*Pinus ponderosa* Dougl.). This is one of the most important of the pines of California. It is abundant in the vicinity of Portola, Quincy and Belden, also abundant in southern California in the San Bernardino mountains at Skyland and occurs in the Santa Cruz mountains.

Jeffrey Pine (*Pinus ponderosa* var. *Jeffreyi* Vasey) commonly has larger cones. It is common near Portola associated with the species.

Big Cone Pine (*Pinus Coulteri* Don.) was not collected, but was observed in the San Bernardino Mountains along the Santa Fe railroad.

Digger Pine (*Pinus sabiniana* Dougl.) was observed in the foothills of the Sierra mountains at altitudes of a few hundred feet to 2,000 feet in the Feather river canon near Oroville.

Torrey Pine (*Pinus Torreyana* Parry). This pine was discovered by Dr. C. C. Parry, botanist of the Mexican Boundary Survey, who was a resident of Davenport, Iowa. This pine is restricted in its distribution. It occurs on the San Diego coast near the mouth of the Soledad river, south of the city of Del Mar and north of La Jolla. Santa Rosa Islands is the only other locality from which the species is reported. A few cultivated trees were observed in San Diego. The tree in its looks is very disappointing but it is unique. No other tree species are found growing with it.

Fig. 48—Characteristic broad expanse of sandy valley and hilly open forest land at junction of Alpine creek with Little Kern river. Forest consists of Jeffrey pine, 15 to 30 trees per acre, and the region has been heavily grazed by cattle and sheep. There is evidence also of fire, which has helped to bare the surface. Sequoia National Forest, Tulare County, California. Courtesy U. S. Forest Service.

Bishop's Pine (*Pinus muricata* Don.) occurs at Monterey.

Monterey Pine (*Pinus radiata* Don.), a beautiful symmetrical tree with a trunk one to four feet in diameter, tan or cinnamon colored cones, is abundant on the Monterey peninsula. The trees are protected by a private corporation which owns much of the land.

Douglas Fir (*Pseudotsuga mucronata* Sudw.). The Douglas fir is widely distributed in California from Portola to Belden in the Feather river cañon, Santa Cruz mountains, Big Trees and Sierra Madre.

White Fir (*Abies concolor* Lindl. and Gord.). Common in the Feather river canyon between Portola and Belden. A large tree with smooth bark.

Redwood (*Sequoia sempervirens* Endl.). Isolated groves are found in the vicinity of San Francisco, Muir Valley, Santa Cruz mountains, Big Trees. The Muir woods contain some fine trees. The Sequoia in the Santa Cruz mountains is associated with the beautiful Chamisso's fern (*Aspidium minutum*), *Umbellularia californica, Quercus chrysolepsis, Acer macrophyllum* and *Alnus rhombifolia*. On some of the stumps of the redwood three generations may be seen. Unlike the pines this species sprouts abundantly and reproduction is plentiful in the canyons and moist slopes.

Incense Cedar (*Libocedrus decurrens* Torr.). The tree resembles an arbor vitae with minute leaves. It is abundant on the mountain slopes associated with the white fir, Douglas fir yellow pine and *Purshia tridentata*. This is true for Feather river canyon about Portola. It was common between Portola and Belden, also near San Bernardino in the mountains of that name and at the summer resort known as Skylands.

Monterey Cypress (*Cupressus macrocarpa* Hartw.) is commonly planted in California. It occus on the ocean shore at Monterey from Pescadero Point to Cypress Point, a strip about two miles long and one-eighth of a mile wide. There is also a little grove at Point Lobos.

Gowen Cypress (*Cupressus goveniana*) occurs on the coast on the west slope of Huckleberry Hill.

California Juniper (*Juniperus californica* Carr). The California juniper is a low tree, often a shrub, found at lower altitudes of the San Bernardino mountains, where it is common.

Western Juniper (*Juniperus occidentalis* Hook.). Not common in the Feather river country. Near Portola a few isolated trees were found.

SALICACEÆ Willow Family.

Yellow Willow (*Salix lasiandra* Benth.). This willow is common along streams, Feather river canyon, Portola and Belden.

Black Willow (*Salix nigra* Marsh.). Along streams, Yuba, Feather river and in the "Great Valley."

Arroya Willow (*Salix lasiolepis* Benth.). This is common in the bottom of streams in southern California. San Diego.

Nuttal Willow (*Salix flavescens* Nutt.). Along the sea coast, San Francisco Bay region.

Cottonwood (*Populus Fremontii* Wats.). This is common along the streams in the Great Valley, Yuba City, southern California, San Diego.

Black Cottonwood (*Populus trichocarpa* T. and G.) is a beautiful tree resembling the balm of Gilead. It is common in the Feather river canyon near Belden, growing in the bottoms.

JUGLANDACEÆ Walnut Family.

California Walnut (*Juglans californica* Wats.). The California walnut is common in the lower parts of the canyons of the San Bernardino mountains. It is a low branching tree. Trees occur in the great northern valley of California. The wood of this species makes beautiful lumber. This form has been called the var. *Hindsii* by Jepson.

BETULACEÆ Birch Family.

White Alder (*Alnus rhombifolia* Nutt.). Common everywhere in the lower Sierras. Abundant along the Feather river in the canyon near Belden, Muir woods and Mill valley, Santa Cruz Mountains, San Lorenzo canyon, Big Trees, mountains near Los Angeles, and the canyons of San Bernardino mountains.

FAGACEÆ Oak Family.

Valley Oak (*Quercus lobata* Nee). The valley oak is one of the most striking trees of the "Great Valley," Sacramento, Marysville, Yuba City, Live Oak, etc. Large trees are found about Yuba City. The trees of the Valley Oak are sometimes eight to ten feet in diameter. The crown is round topped and has pendulous branches.

Oregon Oak (*Quercus Garryana* Dougl.). This oak, of wide distribution on the Pacific Coast reaching up into Oregon, Washington and British Columbia, was observed in the Santa Cruz mountains.

Blue Oak (*Quercus Douglasii* H. and A.). This is an abundant species in the lower Feather river canyon about Belden.

Maul Oak (*Quercus chrysolepis* Liebm.) is another oak of wide distribution, with toothed or entire leaves. Beautiful specimens occur in the Feather river canyon about Belden, Mill Valley, Muir woods and the San Bernardino Mountains in Southern California.

Coast Live Oak (*Quercus agrifolia* Nee). A tree sometimes seventy feet high with short trunk and spreading branches. Found at Berkeley and in the coast ranges southward. Commonly found on the low hills, giving them a unique appearance.

Live Oak (*Quercus Wislizeni* A D C.). Yuba and Feather river valleys. Live Oak.

California Black Oak (*Quercus Kelloggii* Newb.). This species approaches the eastern black oak. A good sized tree on high ridges at Portola at an altitude of 4,500 feet.

Tan Bark Oak (*Pasania densiflora* Oerst.). The tan bark oak has erect staminate flowers resembling *Castanea*, and the fruit is like *Quercus*. The bark of the tree is used extensively for tanning. At Mill Valley it occurred with redwood (*Sequoia sempervirens*).

PLATANACEÆ Sycamore Family.

Sycamore (*Platanus racemosa* Nutt.). The California Sycamore resembles our eastern species but with fruit racemose and widespreading branches. The species occurs in the great valley near Yuba City but is more common southward in the Coast ranges like the Santa Cruz mountains near Big Trees, Santa Barbara and San Bernardino mountains.

LAURACEÆ Laurel Family.

California Laurel or Bay Tree (*Umbellularia californica* Nutt.). Common and abundant everywhere in the lower Feather river canyon, Belden, near Berkeley, in the canyons, and in the Santa Cruz mountains.

ROSACEÆ Rose Family.

Cherry (*Prunus emarginatus* walp.) Belden, Feather river canyon.

Western Choke Cherry (*Prunus demissa* Walp.). Common in the Feather river canyon, Belden.

ACERACEÆ Maple Family.

Large Leaved Maple (*Acer macrophyllum* Pursh). Handsome tree with large leaves, sometimes with a trunk four feet in diameter, sixty-five feet in height. Abundant at Belden, Muir woods, Mill valley, Big Trees, Santa Cruz mountains and San Bernardino mountains.

Box Elder (*Acer negundo* L. var. *Californicum* Sarg.). Common in foothills, Feather river, Yuba City, Marysville and San Bernardino mountains.

CORNACEÆ Dogwood Family.

Flowering Dogwood (*Cornus Nuttallii* Aud.). Feather river canyon, Belden.

ERICACEÆ Heath Family.

Madrone (*Arbutus menziesii* Pursh). The Madrone has a wide range from southern California to Vancouver Island and British Columbia. Lower Feather river canyon, Belden, Big Trees, in the Santa Cruz mountains.

OLEACEÆ Ash Family.

Oregon Ash (*Fraxinus Oregona* Nutt.). Common in lower Feather river canyon, Belden, where it occurs on the mountain sides and valleys.

CAPRIFOLIACEÆ Honey-Suckle Family.

Blue Elderberry (*Sambucus glauca* Nutt.). Lower Feather river canyon, Belden, Big Trees, in the Santa Cruz mountains.

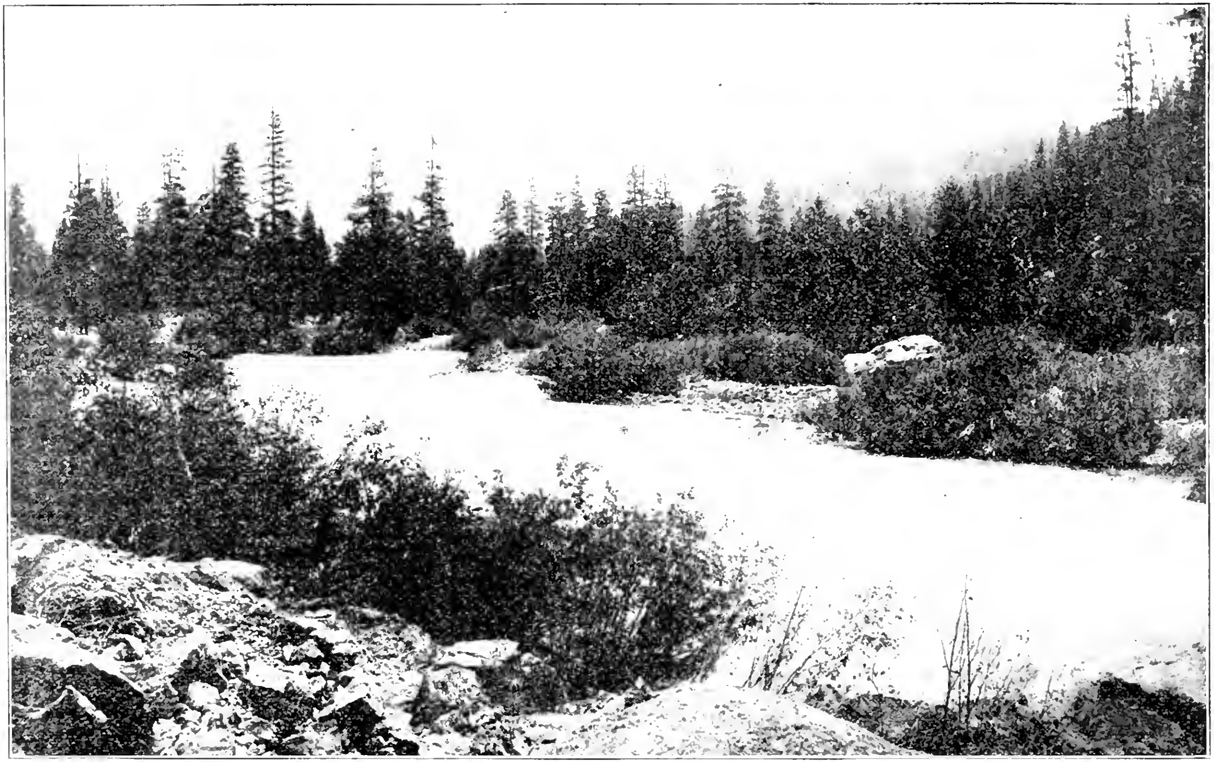
I am indebted to the Western Pacific Railway for Plates XXXII A, XXXIII and XXXIV from the Feather river Canyon and to the Southern Pacific Railway for Plates XXXV and XXXVI. Plate XXXV shows the Redwood in the big tree grove in the Santa Cruz mountains.

For photographs illustrating the Libocedrus, the Valley Oak and Jeffrey Pine, I am indebted to the U. S. Forest Service.

DEPARTMENT OF BOTANY,
IOWA STATE COLLEGE.

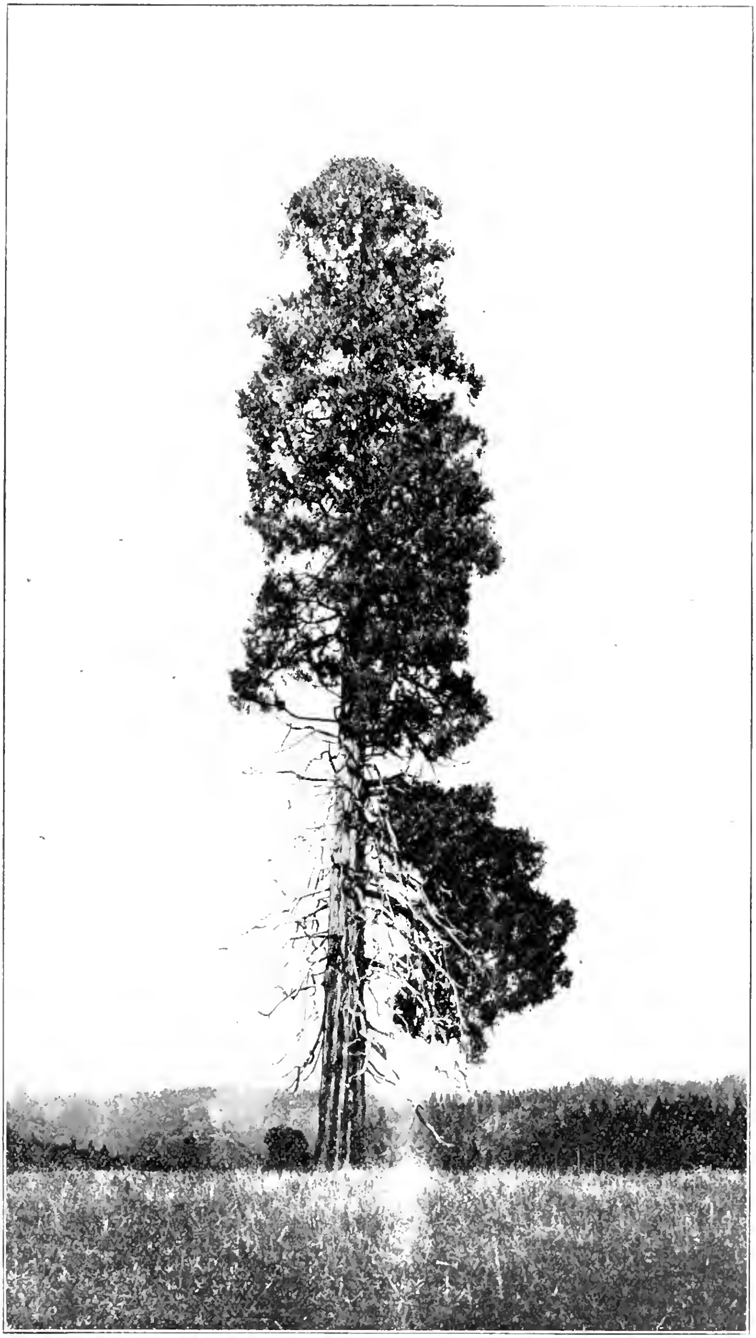
Along the East Branch of Serpentine canon, Feather river. Showing the characteristics of Yellow Pine, Firs and Libocedrus. Courtesy Western Pacific Railroad.

Feather river and Feather river canon near Oroville, showing Yellow Pine in the foreground and the bank of the stream lined with Willows. Along the line of the Western Pacific Railway. Courtesy Western Pacific Railroad



Middle Fork Feather river near Oroville, along the line of the Western Pacific railway; showing Fir (*Abies concolor*) and Yellow Pine (*Pinus ponderosa*). Courtesy Western Pacific Railroad.

San Lorenzo river with Redwood in the distance and Maple and Alder over-hanging the stream. Courtesy Southern Pacific Railroad.



Incense cedar, *Librocedrus decurrens*, El Dorado county, California. Courtesy U. S. Forest Service.

California white oak or valley oak (Quercus lobata), [illegible] feet in diameter. One of the largest found. Monterey county, California. (Courtesy U. S. Forest Service.)

NOTES ON SOME NORTH AMERICAN CONIFERS BASED ON LEAF CHARACTERS.

L. W. DURRELL.

Leaf characters, unlike stem characters, are as a rule subject to such variations that they form an unreliable basis of comparison between plants. Conifer leaves on the contrary, because of their simplicity as compared with other leaves, show a large degree of uniformity, particularly in those characters seen in cross section.

In preparing material for a class in dendrology it occurred to the writer to make sections of conifer leaves to show these leaf characters that they might be used, not wholly as a means of identification in themselves, but to supplement other identifying characters. Leaves of all the arboreal conifers of North America bearing needle leaves (except *Pinus*) were examined and the characters of the same species were found to be constant even though the specimens come from widely separated localities. With this in mind camera-lucida drawings were made of representative sections taken from the middle of mature leaves from different points on the branch, and the drawings supplemented by a description of the section when treated with reagents to differentiate the histological elements.

As the leaf characters of conifers have frequently been discussed and used in identification, the following drawings rather than the keys or description are of most importance, as a means of quick and vivid portrayal of these characters. The drawings endeavor to show all the characters seen in cross section both as a whole and in detail, except in the case of the stomata, which, because of their alternate arrangement in their rows, do not appear in the regular number in any one section.

The scale of magnification for each plate is the same—the drawing of the whole section in each case is enlarged to 40 diameters while the detailed drawings are enlarged to 260 diameters, except in the case of Plates XL and LXVI, which are reduced one-third more than the other plates.

It is interesting to note, in comparing the series of sections, the presence of dichotomy, as manifest in the double vascular bundles, and its disappearance in the higher conifers,—also the development of palisade parenchyma in all flat leaves. Something of phyletic relationship is shown in some of the sections, as for instance, the deeply infolded parenchyma walls of the Larches, linking them with the preceding Pines; with the decrease of the same character to mere corrugations in the parenchyma walls of some of the Spruces. The presence and decrease of a conspicuous bundle sheath as advance is made through the group is also notable.

Note: Throughout the descriptions it has been the aim to describe all the characters seen in section. Most reliance, however, can be placed in the appearance of such characters as the vascular bundles, bundle sheath, resin ducts and hypodermai cells, as they show most constancy.

The characters of the parenchyma and the pithlike cells of the vascular bundles can not be considered as reliable, though the infolding of the walls of the former appear to be uniform.

Throughout the Plates it has been the aim to use uniform means of portrayal. The shaded space without the epidermal cells represents cutin except where this is very thin, where only a line is used to represent its boundaries. In representing the phloem in the bundles single lines are used to distinguish it from the thick walled xylem though in many cases the walls are as thick as those of the xylem cells, though not lignified as is the xylem.

The numbering of the figures of the plates is the same approximately in each case—Figure 1 shows the leaf section as a whole. Figure 2, section of epidermis. Figure 3, section of resin duct if present. Figure 4, section of vascular cylinder.

ARTIFICIAL KEY TO CONIFERS BASED ON LEAF SECTIONS.

I. Leaves 3 to 4-angled, or if compressed without a dorsal groove. Vascular cylinder surrounded by a conspicuous bundle sheath. Vascular bundle obscurely divided. Resin ducts present or absent.

- 2. Walls of parenchyma deeply infolded................. *Larix*
- 2. Walls of parenchyma not infolded, smooth or only slightly corrugated .... *Picea*

I. Leaves more or less flattened, usually grooved above.

- 2. One central resin duct.
  - 3. Two vascular bundles........................... *Tsuga*
  - 3. One vascular bundle, leaves very small, resin duct inconspicuous .... *Taxodium*
  - 3. One vascular bundle, leaves very large, resin duct large .... *Tumion*
- 2. Two lateral resin ducts.
  - 3. Vascular cylinder surrounded by a conspicuous bundle sheath. One vascular bundle... *Pseudotsuga*
  - 3. Vascular cylinder surrounded by a group of pith-like cells or an inconspicuous bundle sheath. Two distinct bundles....................... *Abies*
- 2. Three resin ducts..................... *Sequoia sempervirens*
- 2. No resin ducts. One vascular bundle. Walls of epidermal cells and cutin deeply mammillated....... *Taxus*

KEY TO LARIX.

I. Leaves 3-angled or keeled.

- 2. Leaves distinctly 3-angled. Obscure resin ducts in lateral edges of leaf...................... *L. americana*
- 2. Leaves slightly 3-angled or flat with keel on ventral side. No resin ducts........................ *L. occidentalis*

I. Leaves 4-angled .... *L. Lyallii*

LARIX AMERICANA Michx. Tamarack, Larch.

Leaves decidedly three-angled.

Resin ducts obscure, but present at extreme edges of leaf. They consist of an opening in a cluster of hypodermal cells.

Vascular bundles surrounded by a definite sheath of round unlignified cells. Xylem bands small and divided. A very few isolated lignified cells present in pith.

Hypodermal cells present in small groups at lateral edges of leaf, also one layer along dorsal and ventral midrib. Not lignified.

Epidermal cells small, round and unlignified.

Walls of parenchyma deeply infolded.

Material from trees on Campus of Iowa State College.

LARIX OCCIDENTALIS Nutt. Tamarack.

Leaves more or less flat, keeled below.

Resin ducts none.

Vascular bundle surrounded by a definite sheath of round, lignified, loose joined cells. Xylem in excess of phloem with a band of lignified cells extending from xylem through phloem to a group of lignified strengthening cells below. Xylem bands slightly separated.

Hypodermal cells in a small group at lateral angles, also one layer present along dorsal and ventral midrib. Lignified.

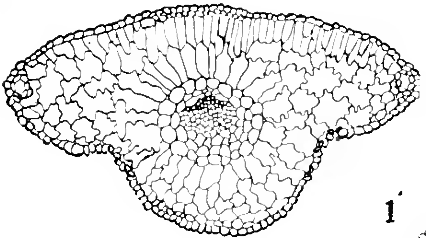
Epidermal cells large, round and lignified.

Parenchyma walls infolded.

Material from University of Washington.

Plate XXXIX.

Figure 1′.—Section of leaf of *Larix americana*.
Figure 1″.—Section of leaf of *L. occidentalis*.
Figure 2″.—Section through stoma of *L. occidentalis*.
Figure 3′.—Section through resin duct of *L. americana*.
Figure 4′.—Section of vascular cylinder of *L. americana*.
Figure 4″.—Section of vascular cylinder of *L. occidentalis*.



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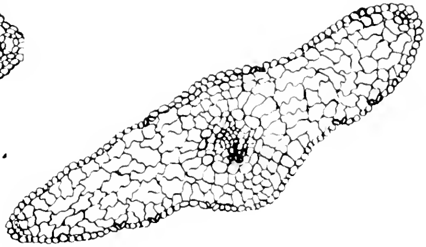

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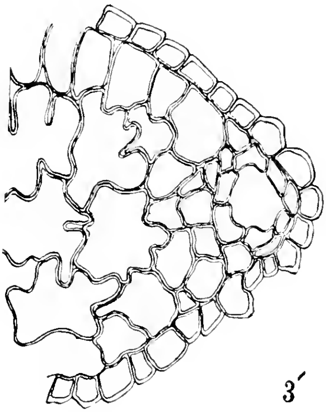

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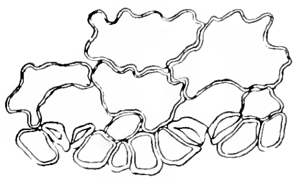

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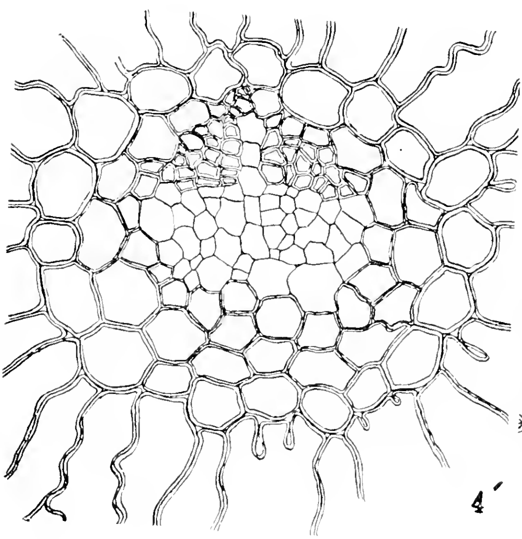

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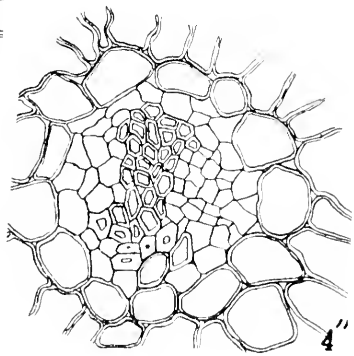


4″

LARIX LYALLII Parl. Tamarack.

Leaves 4 angled, 1—1½ in. long.

Resin ducts absent.

Vascular bundle surrounded by a definite bundle sheath of round unlignified cells. Lignified cells extending in a band across the vascular cylinder comprise the xylem.

Hypodermal cells present at angles of leaves—those at lateral angles in a double layer—lignified epidermal cells small, round, un-uniform in size and unlignified.

Walls of parenchyma not deeply unfolded.

Material from California.

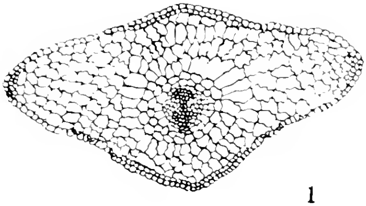
Plate XL.

Figure 1.—Section of leaf of *Larix Lyallii.*

Figure 2.—Section through lower epidermis of leaf of *Larix Lyallii.*

Figure 3.—Section through lateral angle of leaf of *Larix Lyallii.*

Figure 4.—Section of vascular cylinder of leaf of *Larix Lyallii.*



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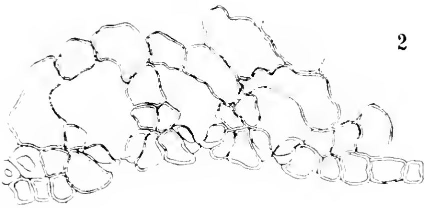

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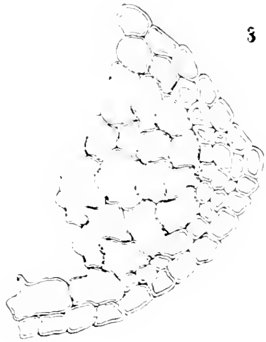

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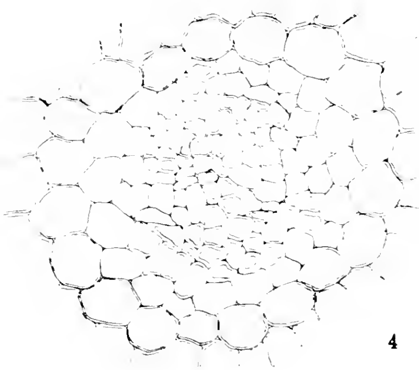


4

KEY TO PICEA.

1. Without resin ducts.
   2. Leaves 4-angled. Three to four rows of stomata on each side of leaf. Parenchyma walls smooth .... *P. canadensis*
   2. Leaves flattened. Two to three rows of stomata on each side of mid-rib on lower surface. Numerous stomata on upper surface............... *P. sitchensis*
1. With resin ducts.
   2. Resin ducts more or less touching lateral angles Leaves 4-angled. Four to seven rows of stomata on each surface........................ *P. parryana*
   2. Resin ducts touching ventral sides.
      3. Leaves more or less 3-angled. Four to five rows of stomata on each upper surface, no stomata on lower surface........ *P. Breweriana*
      3. Leaves 4-angled.
         4. Resin ducts very large, as large as vascular cylinder (in some leaves one or both wanting). Three to five rows of stomata on each surface... *P. Englemanni*
         4. Resin ducts small.
            5. Two layers of cells lining resin ducts. Four rows of stomata on each upper surface. Two rows on each lower surface..... *P. rubens*
            5. One layer of cells lining resin ducts. Four to five rows of stomata on each upper surface. Two to three rows on each lower surface .... *P. mariano*

PICEA MARIANA B. S. & P. Black Spruce.

Leaves 4-angled, $\frac{1}{4}$ to $\frac{3}{4}$ inch long.

Resin ducts 2, small, lateral, touching ventral epidermis, one layer of lignified cells lining the duct.

Vascular bundles—Xylem obscurely separated, cells of pith largely lignified, several large lignified strengthening cells below phloem. Cells of bundle sheath lignified at their juncture.

Hypodermal cells in one layer around entire periphery, lignified.

Epidermis lignified on inner wall.

Parenchyma walls corrugated.

Stomata 2 to 3 rows on lower side.
4 to 5 rows on upper side.

Material from Campus of Iowa Staté College.

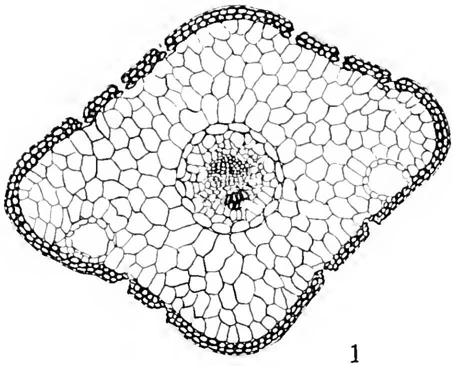
Plate XLI.

Figure 1.—Section of leaf of *Picea mariana.*

Figure 2.—Section through epidermis and stomata of leaf of *P. mariana.*.

Figure 3.—Section through resin duct of leaf of *P. mariana.*

Figure 4.—Section through vascular cylinder of leaf of *P. mariana.*



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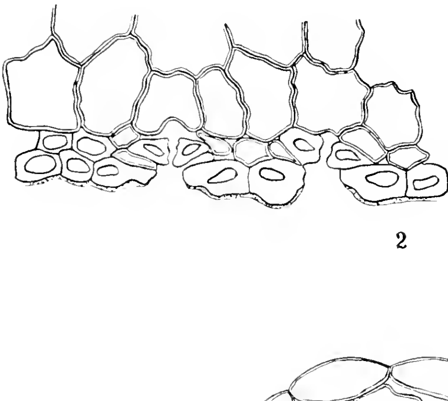

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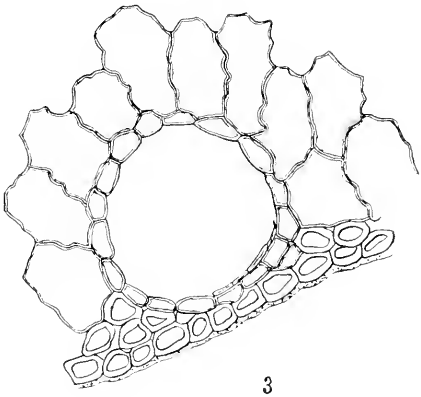

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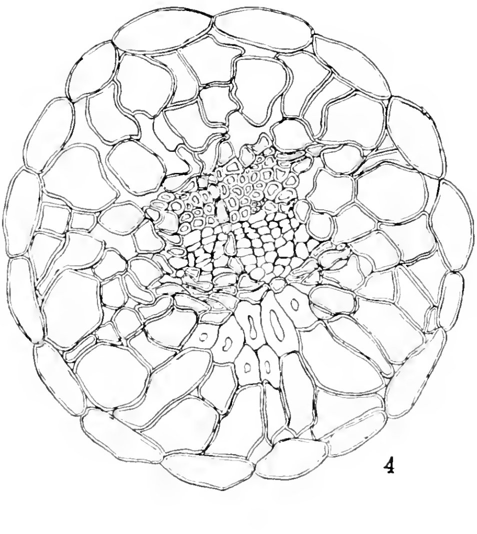

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PICEA RUBENS Sarg. Red Spruce.

Leaves 4-angled, ½ to ⅝ inch long.

Resin ducts 2, small, lateral, touching strengthening cells on ventral side below the angles, ducts lined by two layers of lignified cells.

Vascular bundle—Xylem very slightly divided, a group of thick walled lignified strengthening cells below phloem. No lignification of pith, cells of bundle sheath lignified where joined.

Hypodermal cells around entire periphery, thick walled except along stomata bands, one layer thick and lignified.

Parenchyma walls slightly corrugated.

Stomata 4 rows on each upper side.
2 rows on each lower side.

Material obtained from C. S. Sargent,
Jamaica Plains, Massachusetts.

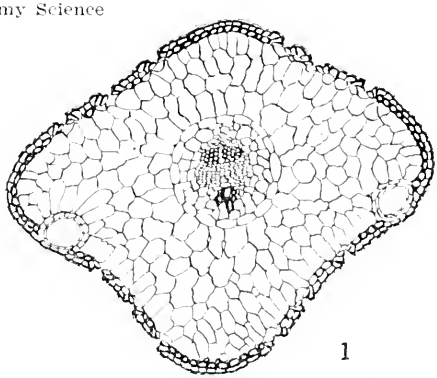
Plate XLII.

Figure 1.—Section of leaf of *Picea rubens.*

Figure 2.—Section through epidermis and stomata of leaf of *P. rubens.*

Figure 3.—Section through resin duct of leaf of P. *rubens.*

Figure 4.—Section through vascular cylinder of leaf of *P. rubens.*



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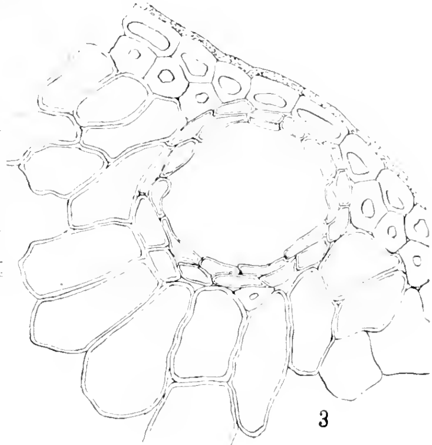

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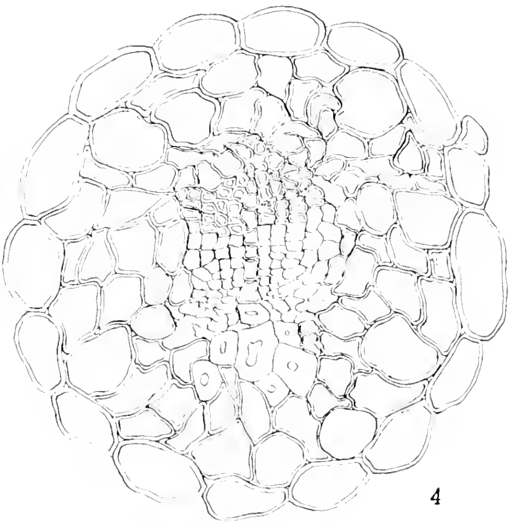

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PICEA CANADENSIS B. S. & P. White Spruce.

Leaves 4-angled, 1/3 to ¾ inch long.

Resin ducts none or rarely one.

Vascular bundles—Xylem bands separated by one row of thin walled cells, cells of pith lignified below phloem, also a few thick walled lignified cells below phloem, bundle sheath not lignified.

Hypodermal cells in one layer around entire periphery lignified.

Parenchyma walls smooth.

Stomata in 3 to 4 rows on each side of leaf.

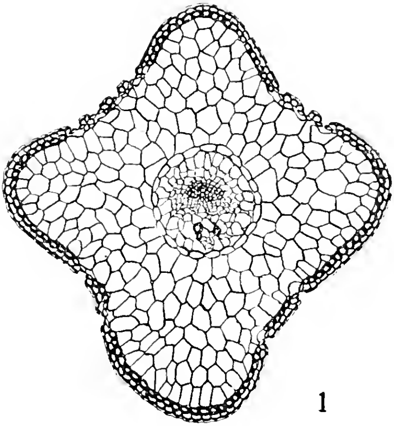
Material from Campus of Iowa State College.

Plate XLIII.

Figure 1.—Section of leaf of *Picea canadensis.*

Figure 2.—Section through epidermis and stomata of leaf of *P. canadensis.*

Figure 4.—Section through vascular cylinder of leaf of *P. canadensis.*



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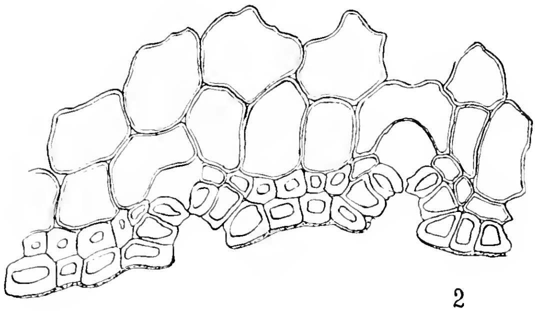

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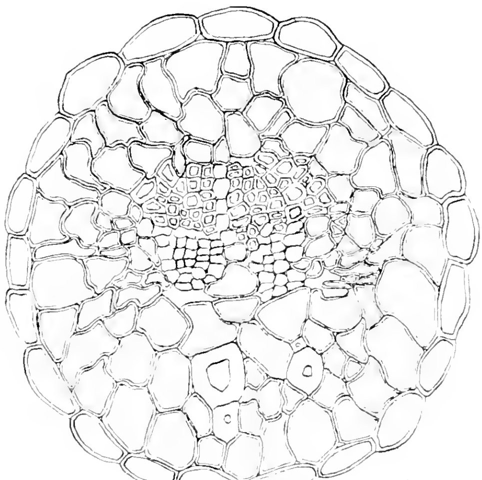

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PICEA ENGELMANNI. Engelm. Engelman Spruce, White Spruce.

Leaves 4-angled, 1 inch to 1⅛ inches long.

Resin ducts 2 (in some leaves 1 or both are missing), very large (as large as vascular cylinder), touching epidermis on ventral side, lined with 2 layers of lignified cells.

Vascular bundles—Xylem most noticeably undivided, pith cells above xylem lignified, large irregular cells in pith below phloem lignified, cells of bundle sheath lignified where joined.

Hypodermal cells present around entire periphery in 1 layer with increases to 2 to 3 layers at angles, heavy walled and lignified.

Parenchyma walls slightly corrugated.

Stomata in 3 to 5 rows on each side.

Material from Herbarium of Iowa State College.

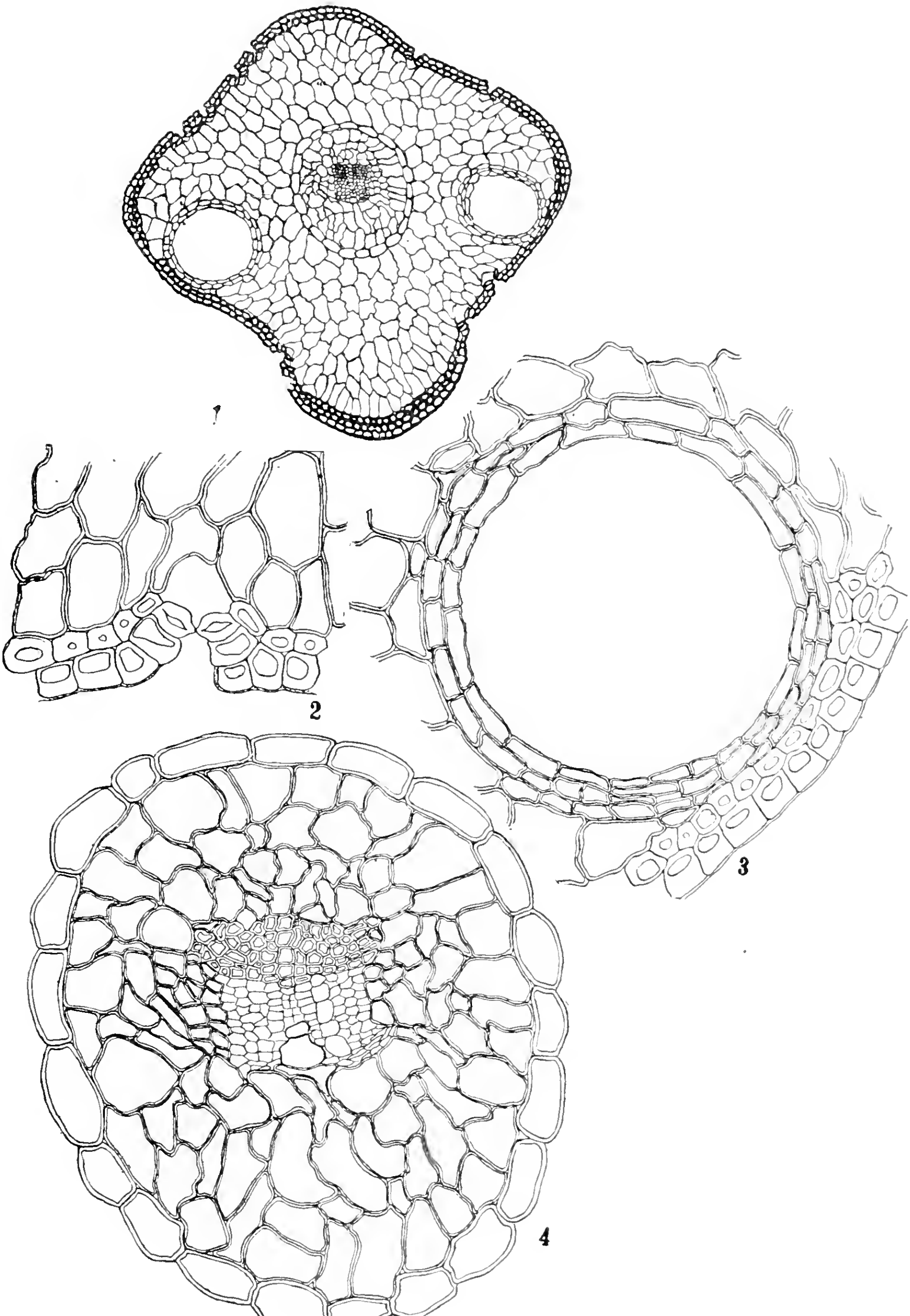
Plate XLIV.

Figure 1.—Section of leaf of *Picea Engelmanni.*

Figure 2.—Section through epidermis asd stomata of leaf of *P. Engelmanni.*

Figure 3.—Section through resin duct of leaf of *P. Engelmanni.*

Figure 4.—Section through vascular cylinder of leaf of *P. Engelmanni.*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PICEA PARRYANA Sarg. Blue Spruce.

Leaves 4-angled, 1 inch to $1\frac{1}{8}$ inches long.

Resin ducts 2, large, at lateral angles of leaves or slightly below the angles, 2 rows of cells lining ducts, inner layer of lignified, irregular flat cells.

Vascular bundle—Xylem bundles separated by two rows of long narrow lignified cells, large irregular cells above xylem lignified, also the large irregular cells below phloem lignified, cells of bundle sheath lignified where joined.

Hypodermal cells lignified, in 1 row around entire periphery, thickening into 2 rows at upper and lower angles of leaf.

Parenchyma walls smooth.

Stomata in 4 to 7 rows on each side of leaf.

Material from Campus of Iowa State College.

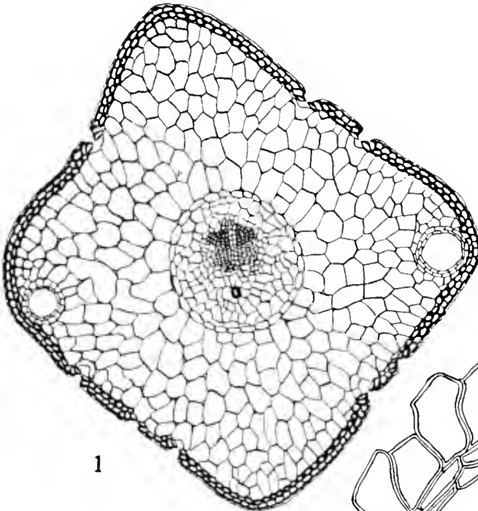
Plate XLV.

Figure 1.—Section of leaf of *Picea parryana* (*pungens*).

Figure 2.—Section through epidermis and stomata of leaf of *P. parryana*.

Figure 3.—Section through resin duct of leaf of *P. parryana*.

Figure 4.—Section through vascular cylinder of leaf of *P. parryana*.



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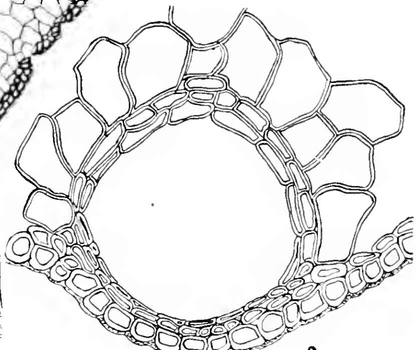

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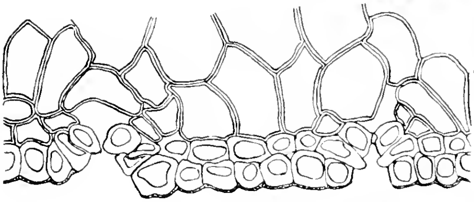

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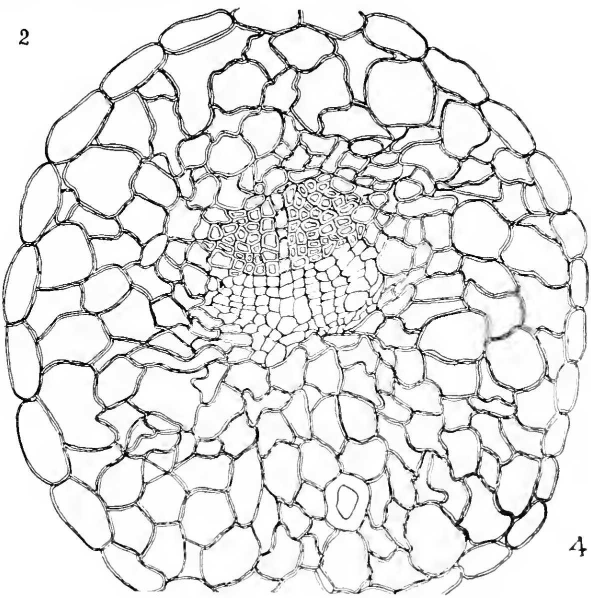

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PICEA BREWERIANA Wats. Weeping Spruce.

Leaf flat, 3-sided. (The lower side is the flat side), ¾ inch to 1½ inches long.

Resin ducts 2, large, lateral, touching ventral epidermis, lined with 2 layers of flat cells, inner layer lignified.

Vascular bundle—Xylem bundles very small, separated by 2 rows of irregular, lignified cells. Phloem band large, cells of pith largely lignified, cells of bundle sheath lignified where joined to each other.

Hypodermal cells very pronounced around entire periphery except on upper side along bands of stomata, 2 rows deep, 3 rows deep at angles.

Epidermis cutinized in thick outer walls, inner wall lignified.

Stomata in broad bands on upper surface only, 4 to 5 rows in each band.

Parenchyma deeply corrugated.

Material from State House grounds, Sacramento, California.

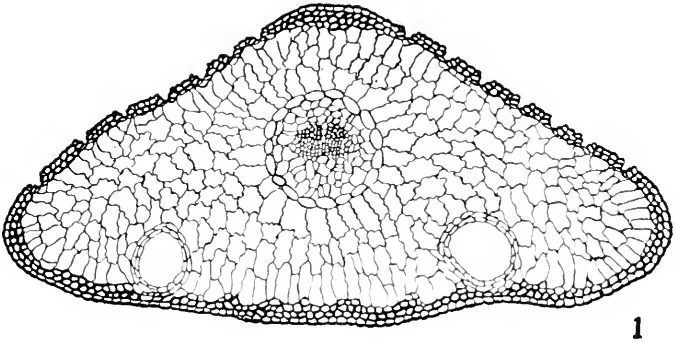
Plate XLVI.

Figure 1.—Section of leaf of *P. breweriana.*

Figure 2.—Section through epidermis and stomata of leaf of *P. breweriana.*

Figure 3.—Section through resin duct of leaf of *P. breweriana.*

Figure 4.—Section through vascular cylinder of leaf of *P. breweriana.*



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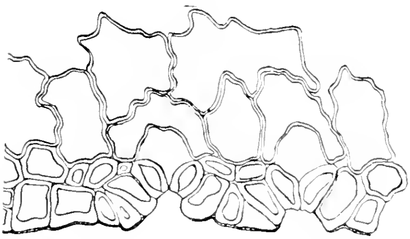

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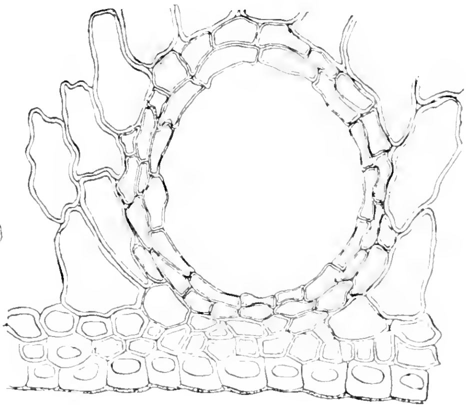

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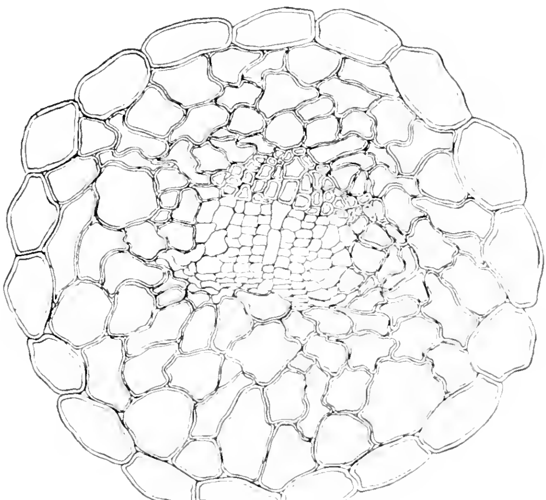

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PICEA SITCHENSIS Carr. Sitka Spruce.

Leaves flat. ½ inch to 1½ inches long.

Resin ducts none.

Vascular bundles—Xylem not apparently separated, cells of pith above xylem and below phloem lignified, lignified strengthening cells present below phloem, bundle sheath somewhat lignified.

Hypodermal cells lignified, in one layer except at lateral edges of leaf and in dorsal and ventral angles where there is an increase of 2 to 3 layers. Thinner walled hypodermal cells below epidermis between the angles of the leaf on ventral side.

Parenchyma walls deeply corrugated.

Stomata occasionally in 2 to 3 rows on each side of midrib on lower surface, numerous stomata on upper surface.

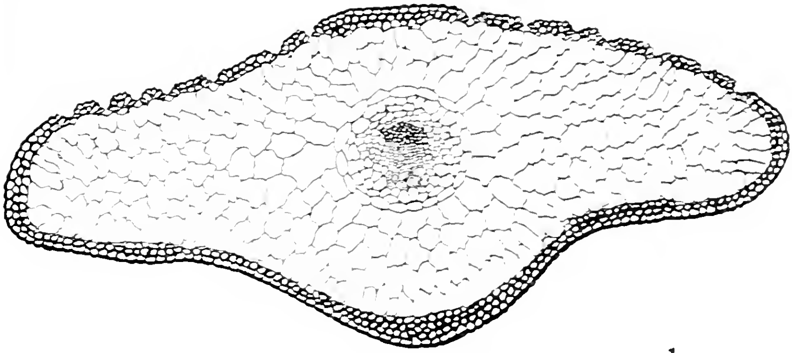
Materials from University of Washington and from State House grounds, Sacramento, California.

Plate XLVII.

Figure 1.—Section of leaf of *Picea sitchensis*.

Figure 2.—Section through epidermis and stomata of leaf of *P. sitchensis*.

Figure 4.—Section through vascular cylinder of leaf of *P. sitchensis*.



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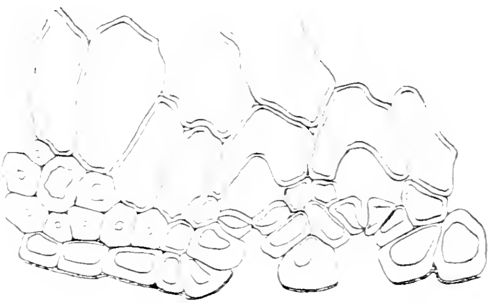

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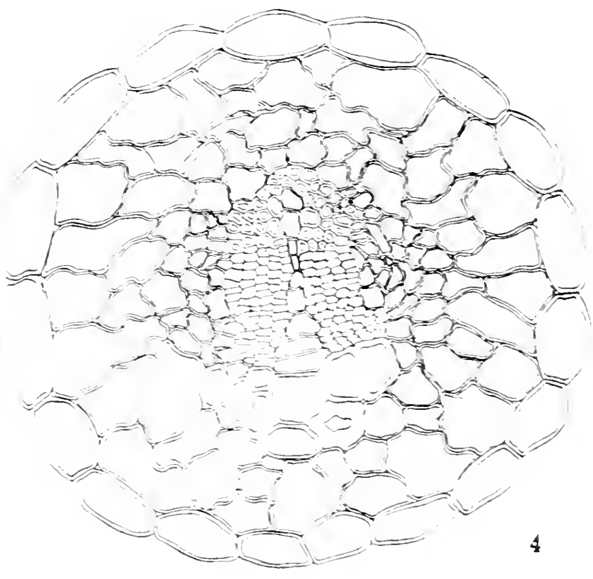

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KEY TO TSUGA.

1. Leaves flat.
   2. Five to six rows of stomata on each side of midrib...... .... *T. canadensis*
   2. Seven to eight rows of stomata on each side of midrib. Cells of upper palisade not deep. Cells of parenchyma along lower surface irregular, or in shallow palisade arrangement. Secretory cells of resin duct not conspicuously one-layered.................... *T. caroliniana*
   2. Seven to nine rows of stomata on each side of midrib. Deep and narrow palisade on upper surface. Cells of parenchyma on lower surface having greatest length laterally. Secretory cells of resin duct conspicuously one-layered .... *T. heterophylla*
1. Leaves concave above. Stomata on both surfaces. Eight rows on each side of midrib on ventral surface..................... *T. mertensiana*

TSUGA CANADENSIS Carr. Hemlock.

Leaves flat, grooved on top, 1/3 to 2/3 inch long, edges tend to turn up.

Resin duct 1, large, central, on ventral side touching epidermis, lined with 1 layer of thin flat lignified cells.

Vascular bundles enclosed in an inconspicuous sheath of large, round, loosely joined cells. Xylem bundles very small, scarcely separated. No other cells except those of xylem lignified.

Hypodermal cells sometimes present along dorsal groove. Epidermis not lignified, guard cells and those cells adjacent lignified.

Stomata on lower surface, 5 to 6 rows each side of midrib.

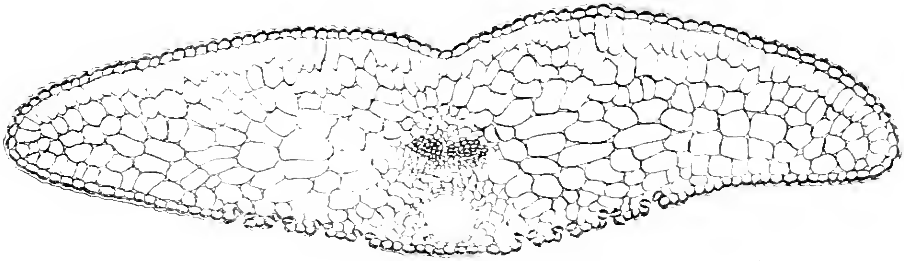
Material from Campus of Iowa State College.

Plate XLVIII.

Figure 1.—Section of leaf of *Tsuga canadensis.*

Figure 2.—Section through epidermis and stomata of leaf of *T. canadensis.*

Figure 4.—Section through vascular cylinder and resin duct of leaf of *T. canadensis.*



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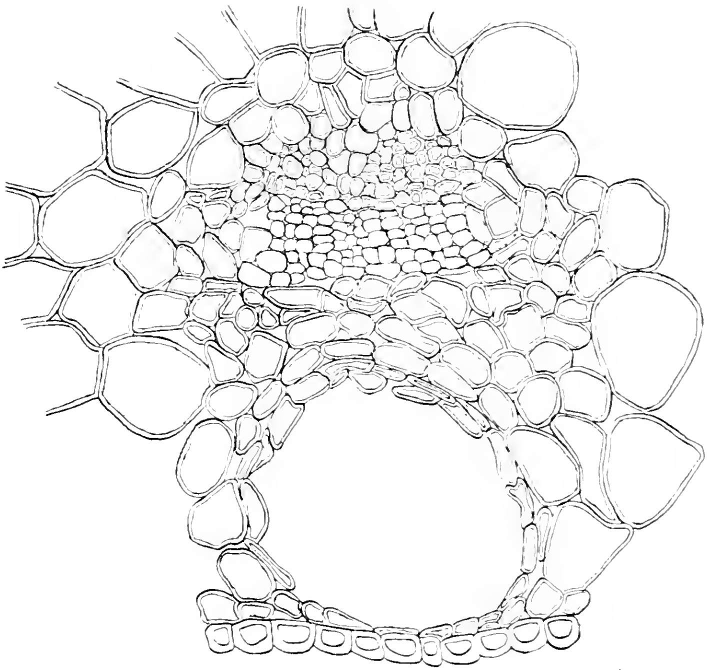

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TSUGA CAROLINIANA Engelm. Hemlock.

Leaf flat, straight, 1/3 to 3/4 inch long.

Resin duct 1, small, central, touching hypodermal cells adjoining epidermis; lined with a layer of flat lignified cells.

Vascular bundle enclosed in a sheath of large, round, loosely joined cells. Xylem bundle small and separated by a layer of large thin walled cells. Two groups of lignified cells at each side of phloem.

Hypodermal cells in angles formed by epidermis and resin duct at edges of leaf and a few scattered singly on dorsal side.

Stomata in bands of 7 to 8 rows each on ventral side either side of midrib.

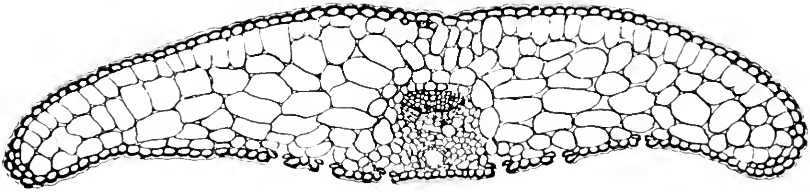
Material from Biltmore, North Carolina.

Plate XLIX.

Figure 1.—Section of leaf of *Tsuga caroliniana*.

Figure 2.—Section through epidermis and stoma of *T. caroliniana*.

Figure 4.—Section through vascular cylinder and resin duct of leaf of *T. caroliniana*.



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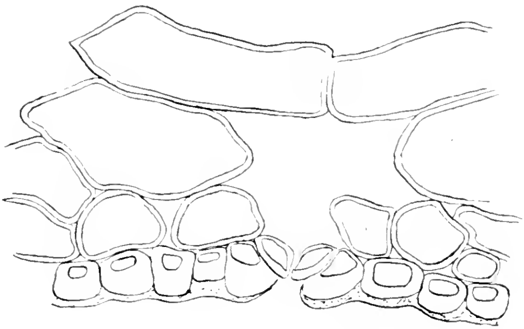

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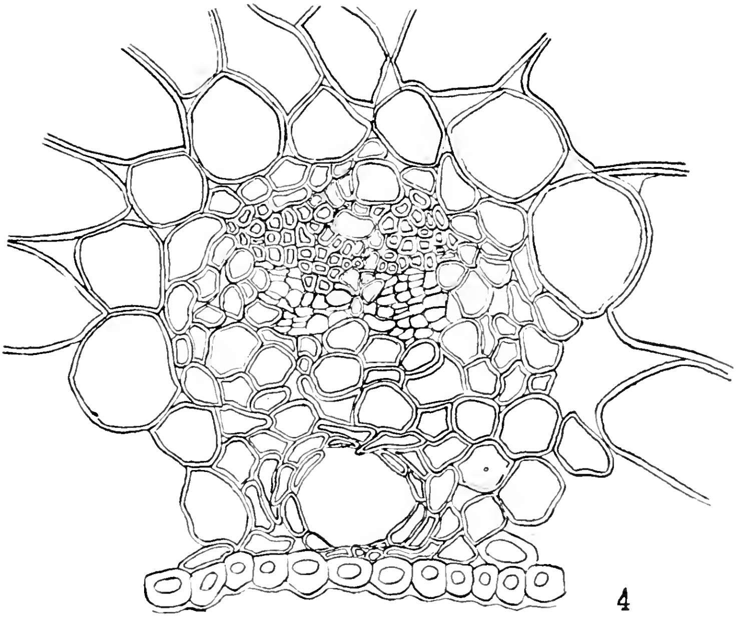

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TSUGA HETEROPHYLLA Sarg. Hemlock.

Leaves flat, edges tending downward, 1/4 to 3/4 inch long, grooved top.

Resin duct 1, large, lined with 2 layers of cells, inner layer consisting of large, round, unlignified cells.

Vascular bundles enclosed in a sheath of large loose cells; within the sheath, in addition to vascular bundle, lie a few lignified cells below and at each side of phloem.

Hypodermal, lignified cells present along lateral edges of leaf and along dorsal groove. Walls of guard cells lignified.

Stomata in bands of 7 to 9 rows along each side of midrib.

Parenchyma along ventral surface of leaf, having cells arranged with greatest length laterally.

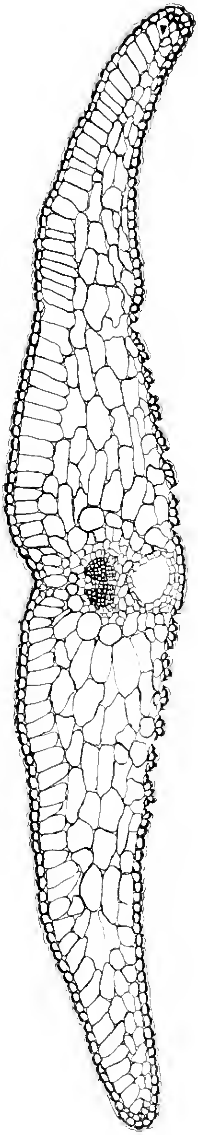
Material from University of Washington, Seattle.

Plate L.

Figure 1.—Section of leaf of *Tsuga heterophylla.*

Figure 2.—Section through epidermis and stomata of leaf of *T. heterophylla.*

Figure 4.—Section through vascular cylinder and resin duct of leaf of *T. heterophylla.*



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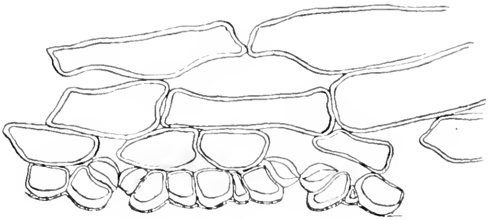

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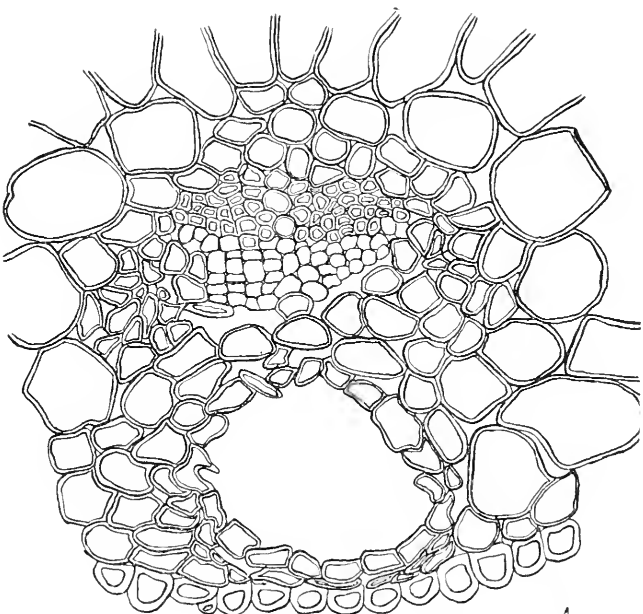

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TSUGA MERTENSIANA Sarg. Mountain Hemlock.

Leaves flat, grooved on top, edges tending down, 1-12 to 1 inch long.

Resin duct 1, small, central, on ventral side touching epidermis; cells lining duct not in a definite layer.

Vascular bundle enclosed in an obscure sheath of large, round, loosely joined cells, xylem bundles small, separated by 1 or 2 rows of unlignified cells, groups of cells in pith on each side of phloem lignified.

Hypodermal cells present only at edges of leaf, cells lignified also at point where duct and epidermis touch; guards cells lignified.

Stomata on both surfaces, 8 rows on each side of midrib on ventral surface.

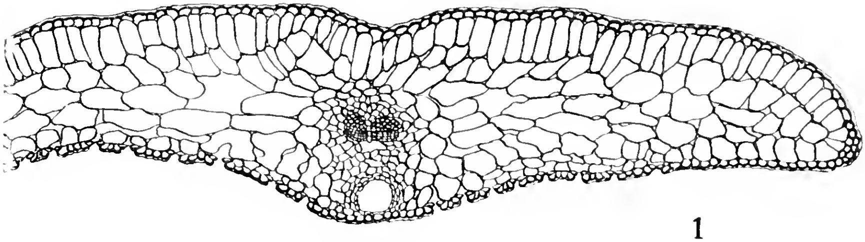
Material from Jamaica Plains, Massachusetts.

Plate LI.

Figure 1.—Section of leaf of *Tsuga mertensiana*.

Figure 2.—Section through epidermis and stomata of leaf of *T. mertensiana*.

Figure 4.—Section through vascular cylinder and resin duct of leaf of *T. mertensiana*.



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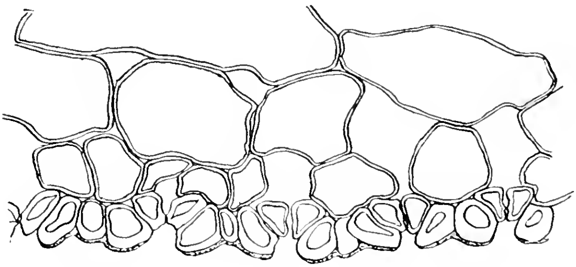

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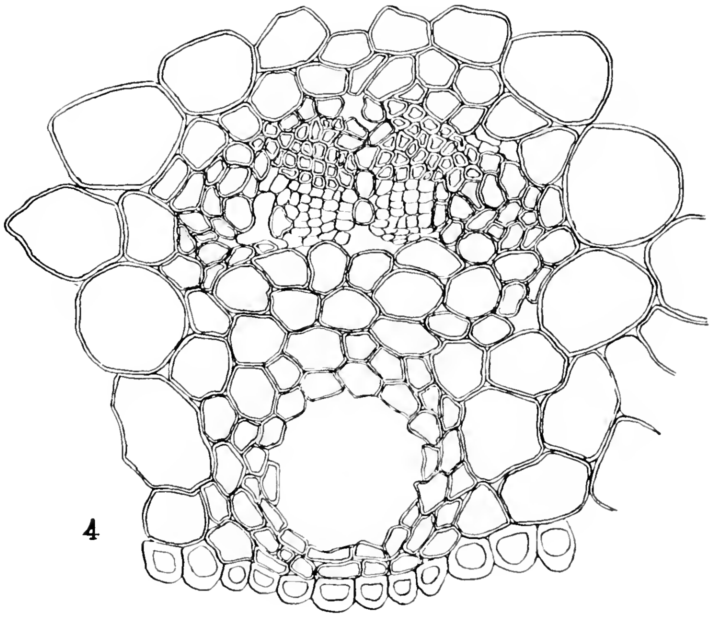

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PSEUDOTSUGA MUCRONATA Sudw. Douglas Fir.

Leaves flat, notched above and keeled below, 3/4 inch to 1 1/4 inches long.

Resin ducts, 2, lateral and touching epidermis on ventral side, ducts lined with 2 layers of cells, lignified where touching epidermis.

Vascular bundle surrounded by a most pronounced bundle sheath of lignified cells. Xylem bundles appearing as one, cells below phloem and above xylem lignified.

Hypodermal cells present in 1 to 3 layers along dorsal and ventral midrib, heavily lignified.

Epidermis cells mammillated, mammillation most pronounced on ventral surface.

Walls of parenchyma corrugated.

Stomata on lower surface.

Material from Campus and herbarium of Iowa State College; Jamaica Plains, Massachusetts; University of Washington, Seattle; State House grounds, Sacramento, California; and University of California.

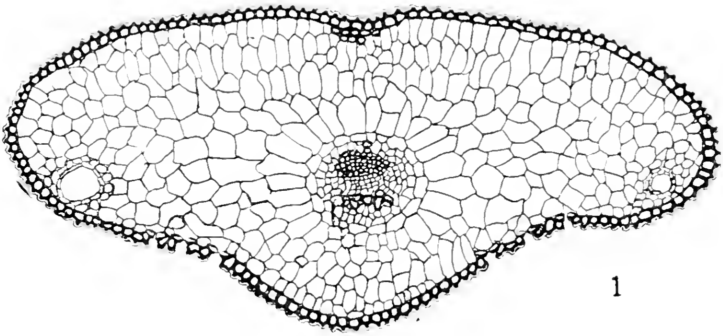
Plate LII.

Figure 1.—Section of leaf of *Pseudotsuga mucronata*.

Figure 2.—Section through epidermis and stoma of leaf of *P. mucronata*.

Figure 3.—Section through resin duct of leaf of *P. mucronata*.

Figure 4.—Section through vascular cylinder of leaf of *P. mucronata*.



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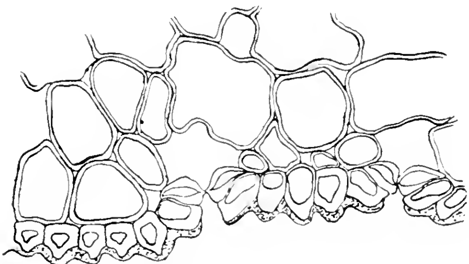

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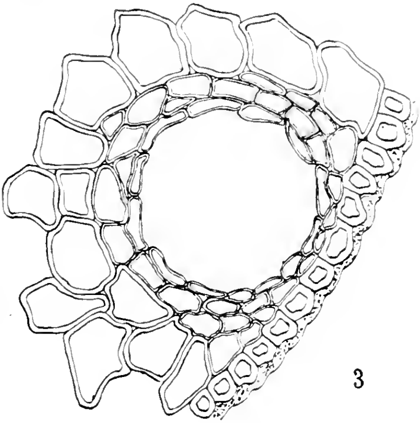

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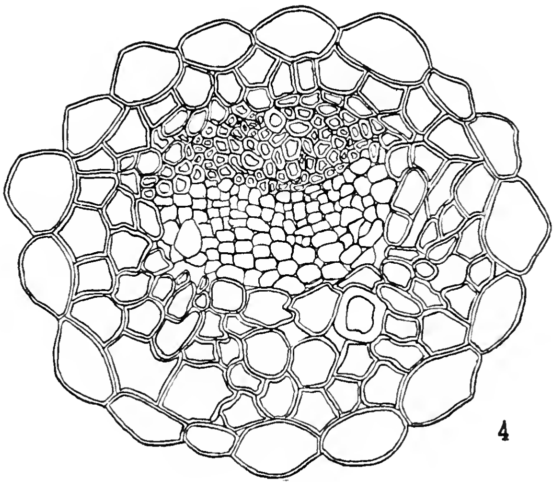

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PSEUDOTSUGA MACROCARPA Mayr. Hemlock.

Leaves flat, grooved above, keeled below, edges tending downward. ¾ inch to 1¼ inches long.

Resin ducts 2, lateral, lignified where touching ventral epidermis.

Vascular bundle surrounded by a most pronounced bundle sheath, cells of sheath lignified. Xylem appears as one bundle with only a slight demarcation. Lignified strengthening cells present below phloem and a wide band of lignified cells extend from xylem through center of phloem.

Hypodermal cells present in one layer around entire periphery. Walls lignified and very thick.

Cells of epidermis mammillated.

Stomata on ventral surface.

Material from Herbarium of Iowa State College; from San Bernardino, California, and from State House grounds, Sacramento, California.

Plate LIII.

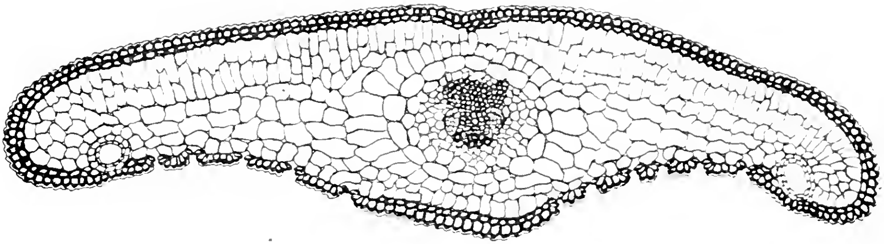
Figure 1.—Section of leaf of *Pseudotsuga macrocarpa.*

Figure 2.—Section through epidermis of leaf of *P. macrocarpa.*

Figure 3.—Section through resin duct of leaf of *P. macrocarpa.*

Figure 4.—Section through vascular cylinder of leaf of *P. macrocarpa.*

Note: The distinguishing feature between the leaves of the two species of Pseudotsuga consists in the presence of a continuous band of heavy walled, lignified, hypodermal cells in the leaf of *P. macrocarpa* and the absence of the same, except along the midrib, in *P. mucronata.* This fact tallies with the environmental conditions under which the trees grow, as *P. macrocarpa* lives under more xerophytic conditions than *P. mucronata.*



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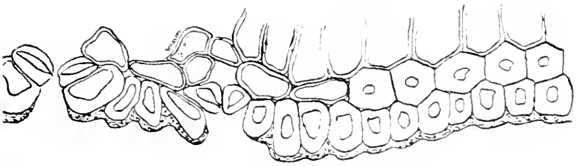

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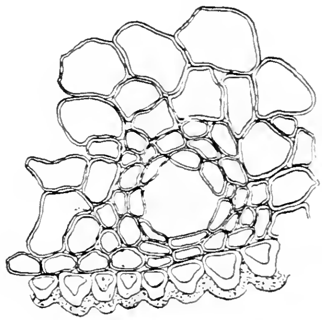

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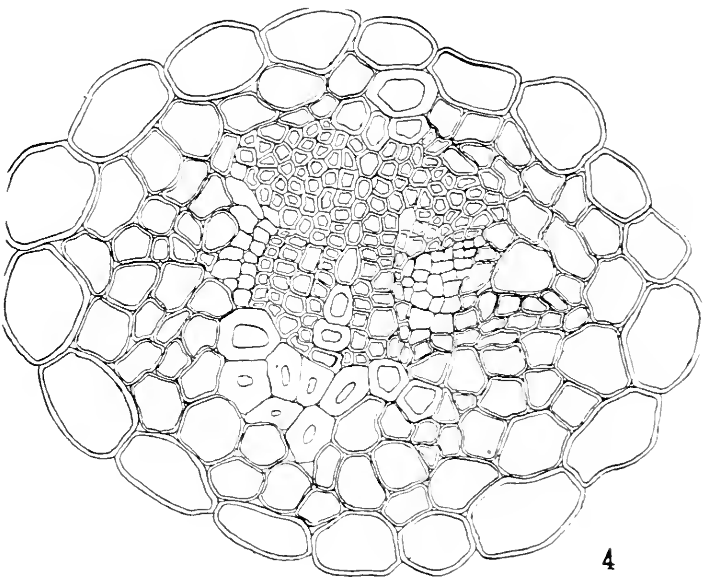


4

KEY TO SPECIES OF ABIES.

1. Leaves flat.
    2. Resin duct lateral and interparenchymal.
        3. Hypodermal cells not present, stomata 4 to 8 rows on lower side.......................... *A. balsamea*
        3. Hypodermal cells present.
            4. Stomata on lower surface only, 8 to 12 rows .... *A. Fraseri*
            4. Stomata on upper and lower surfaces, 8 to 10 rows below, indefinite number above..... .... *A. lasiocarpa*
    2. Resin ducts lateral, touching lower epidermis.
        3. Hypodermal cells present on dorsal side in continuous layer, or around entire periphery, except along bands of stomata.
            4. Stomata not present on dorsal surface.
                5. Leaf small, deeply grooved. Margins curving up. Stomata in bands of 6 to 8 rows each.............. *A. amabilis*
                5. Leaf very long, flat or slightly rounded on upper side. Eight to sixteen rows of stomata in each band..... *A. venusta*
            4. Stomata present on both dorsal and ventral surface, leaf deeply notched above.. *A. nobilis*
        3. Hypodermal cells present only in lateral angles of leaf, and along ventral midrib or in groups of 2 or 3 along dorsal side.
            4. Stomata on ventral surface only...... *A. grandis*
            4. Stomata on both dorsal and ventral surfaces .... *A. concolor*
1. Leaves 4-angled or rounded.
    2. Bundle sheath obscure. Vascular bundles close together. The same number of rows of stomata on all surfaces .... *A. magnifica*
    2. Bundle sheath distinct. Vascular bundles far apart. Rows of stomata more numerous on lower surface... .... *A. nobilis*

ABIES FRASERI Poir. Balsam Fir.

Leaves flat, edges tending down, ½ to 1 inch long.

Resin ducts large, lateral and more or less touching ventral epidermis, lined with two rows of cells.

Vascular bundles small, enclosed in a sheath of large, round, loosely joined cells; xylem bundles small and close together, separated by a band of thin walled cells, one row wide. The thin walled irregular cells present below and between phloem are lignified.

Hypodermal cells present in angles made by ducts and epidermis, and in small number along midrib.

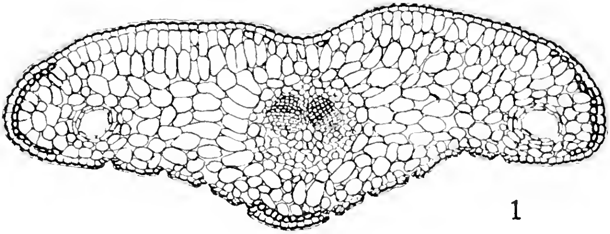
Epidermis not lignified.

Stomata present on lower surface in band of 8 to 12 rows each side of midrib.

Material from Jamaica Plains, Massachusetts.

Plate LIV.

Figure 1.—Section of leaf of *Abies fraseri*.
Figure 2.—Section of epidermis and stomata, leaf of *A. fraseri*.
Figure 3.—Section through resin duct of leaf of *A. fraseri*.
Figure 4.—Section of vascular cylinder, leaf of *A. fraseri*.



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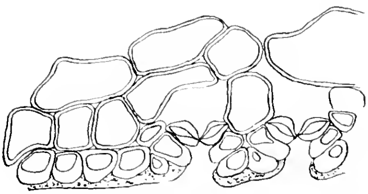

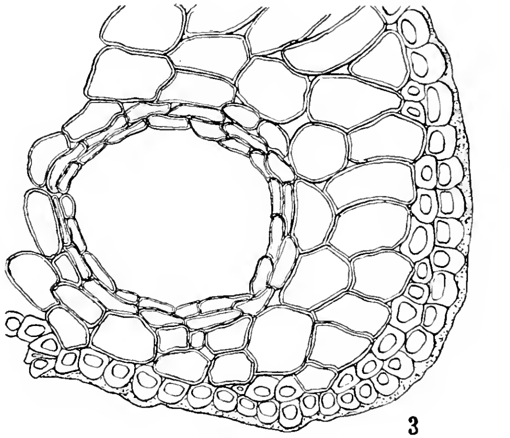

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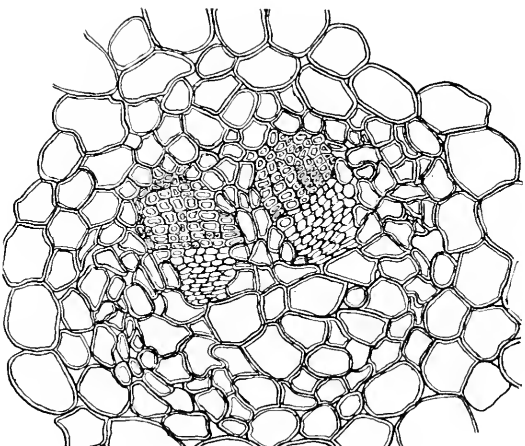

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ABIES BALSAMEA Mill. Balsam Fir.

Leaves flat, edges tending down, ½ inch to 1¼ inches long.

Resin ducts interparenchymal, lined by two layers of unlignified cells.

Vascular bundle surrounded by a slightly differentiated bundle sheath of large, loose cells, lignified where joined together; most of cells in pith below phloem lignified.

Hypodermal cells not present or seldom so. No lignification of epidermis except guard cells.

Stomata in 4 to 8 rows each side of mid rib on lower surface.

Material from Cass Lake, Minnesota.

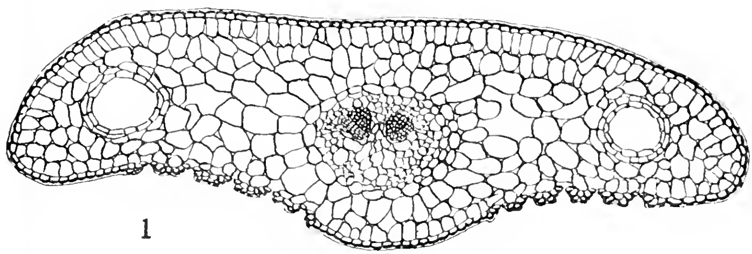
Plate LV.

Figure 1.—Section of leaf of *Abies balsamea.*

Figure 2.—Section through epidermis and stomata of leaf of *A. balsamea.*

Figure 3.—Section through resin duct of leaf of *A. balsamea.*

Figure 4.—Section through vascular cylinder of leaf of *A. balsamea.*



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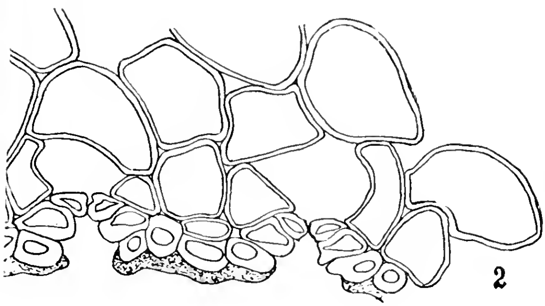

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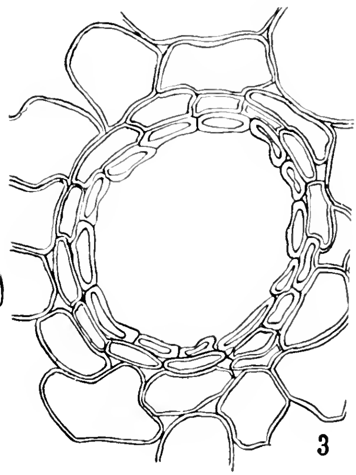

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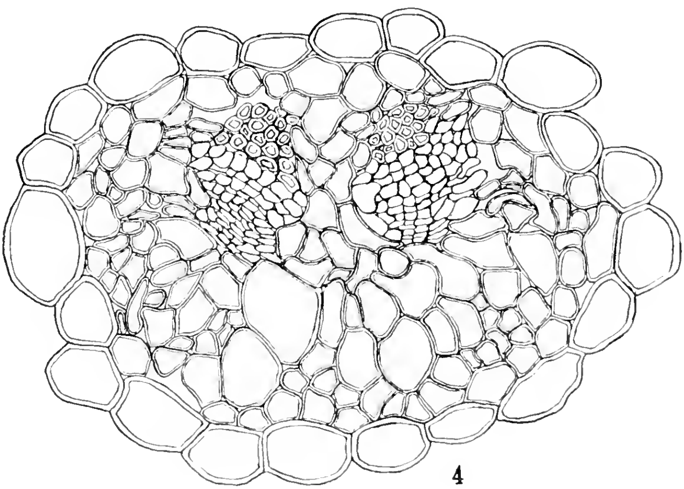


4

ABIES AMABILIS Forbes. White Fir.

Leaves flat, edges turned up, ¾ inch to 1¼ inches long.

Resin ducts lateral, touching epidermis on ventral side, lined with two layers of unlignified cells.

Vascular bundles surrounded by a sheath of large, round, loosely joined cells, xylem bundles small, separated by a band of 2 to 3 rows of lignified cells; a group of large cells below phloem lignified.

Hypodermal cells present around entire periphery except along bands of stomata. Walls of these cells very thick and lignified; the inner walls of the epidermis lignified.

Stomata on lower surface, 6 to 8 rows each side of midrib.

Material from Jamaica Plains, Massachusetts.

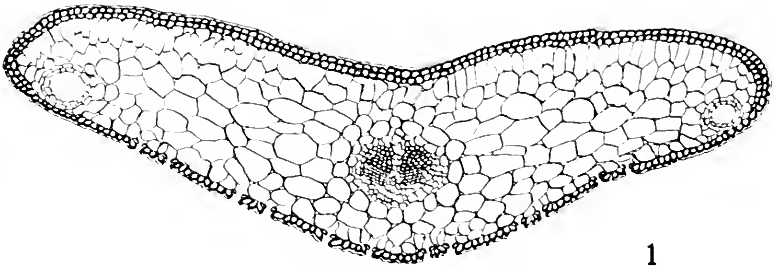
Plate LVI.

Figure 1.—Section of leaf of *Abies amabilis.*

Figure 2.—Section through epidermis and stomata of leaf of *A. amabilis.*

Figure 3.—Section through resin duct of leaf of *A. amabilis.*

Figure 4.—Section through vascular cylinder of leaf of *A. amabilis.*



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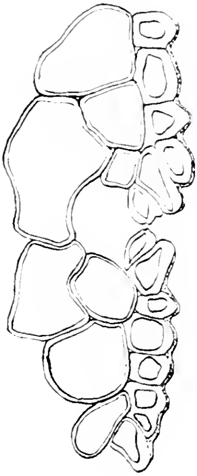

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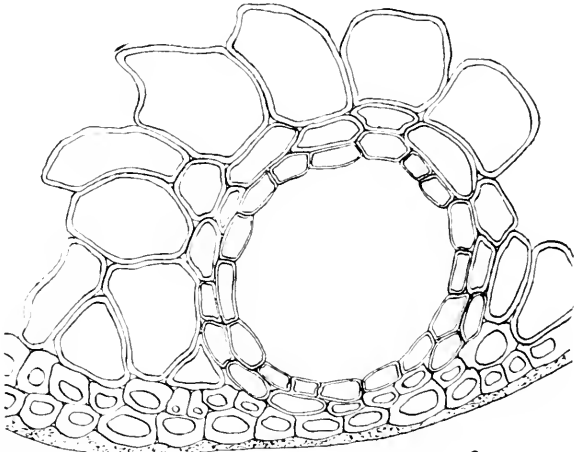

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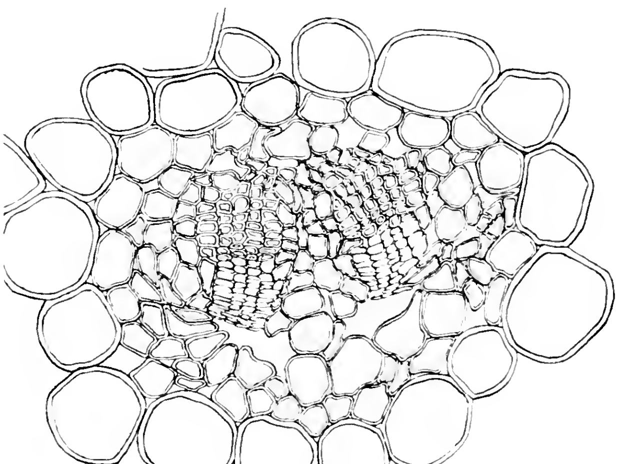


4

ABIES GRANDIS Lindl. White Fir.

Leaves flat, edges tending down, 1½ to 2¼ inches long.

Resin ducts small, lateral, touching epidermis on ventral side, lined with 2 layers of cells.

Vascular bundles surrounded by a sheath of large, round, loosely joined cells. The large irregular cells separating the bundles and those below lignified.

Hypodermal cells present within epidermal layer between bands of stomata on lower side, at the edges of the leaf, and scattered in groups of 1 or 2 along upper surface. Epidermal cell walls not lignified.

Stomata present on lower surface of leaf, 7 to 10 rows each side of midrib.

Material from Jamaica Plains, Massachusetts.

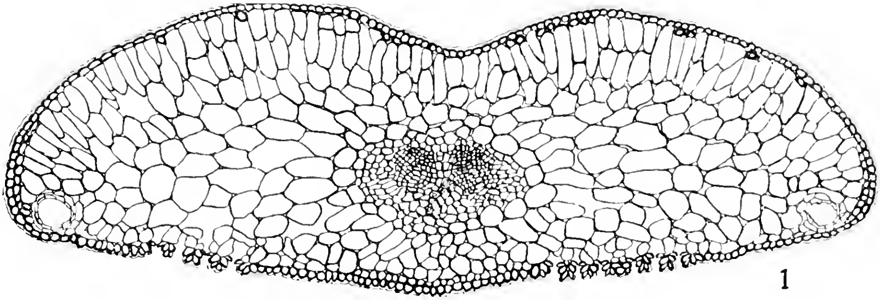
Plate LVII.

Figure 1.—Section of leaf of *Abies grandis.*

Figure 2.—Section through epidermis and stomata of leaf of *A. grandis.*

Figure 3.—Section through resin duct of leaf of A. *grandis.*

Figure 4.—Section through vascular cylinder of leaf of *A. grandis.*



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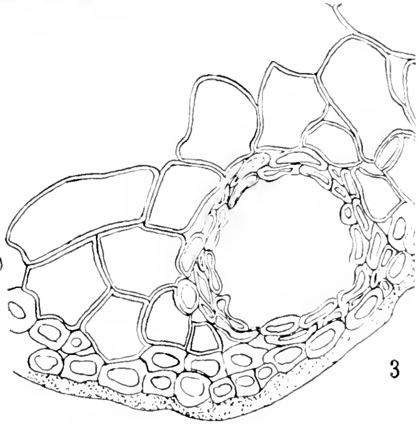

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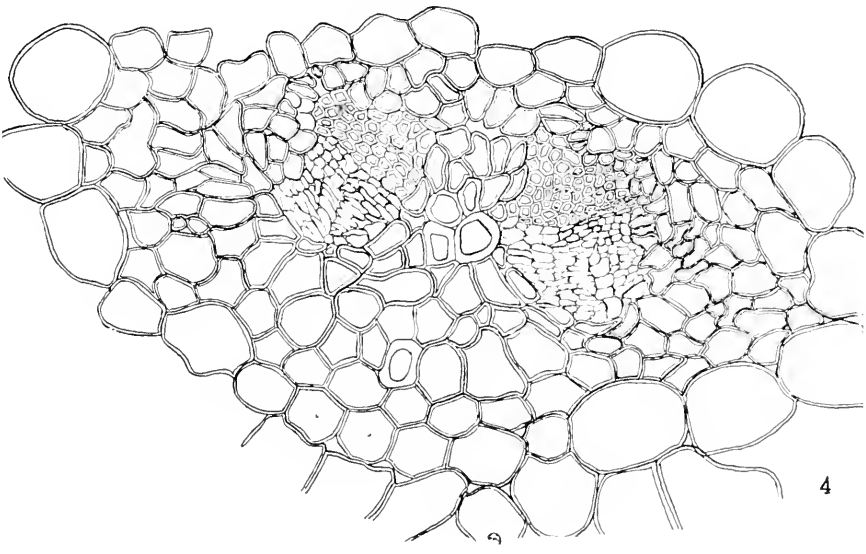


4

ABIES LASIOCARPA Nutt. Balsam Fir.

Leaves flat, 1 inch to 1¾ inches long.

Resin ducts large, interparenchymal, and lateral; lined by 2 rows of thin cells.

Vascular bundles small and near upper margin of vascular cylinder. The large loose cells below phloem are lignified.

Hypodermal cells present below epidermis at lateral edges, and between the bands of stomata on lower surface. Inner walls of epidermis lignified.

Stomata present, in 4 to 5 rows each side of midrib on dorsal side and 7 to 8 rows each side of midrib on ventral side.

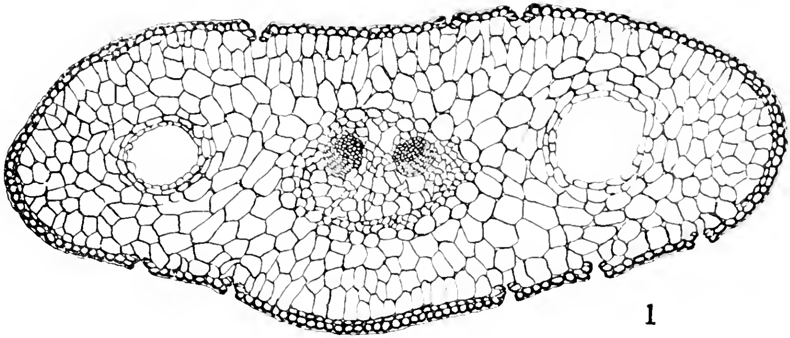
Material from Jamaica Plains, Massachusetts.

Plate LVIII.

Figure 1.—Section of leaf of *Abies lasiocarpa.*

Figure 2.—Section through epidermis and stoma of leaf of *A. lasiocarpa.*

Figure 4.—Section through vascular cylinder of leaf of *A. lasiocarpa.*



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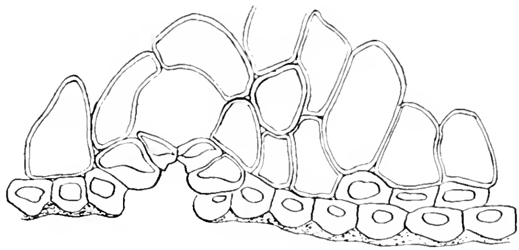

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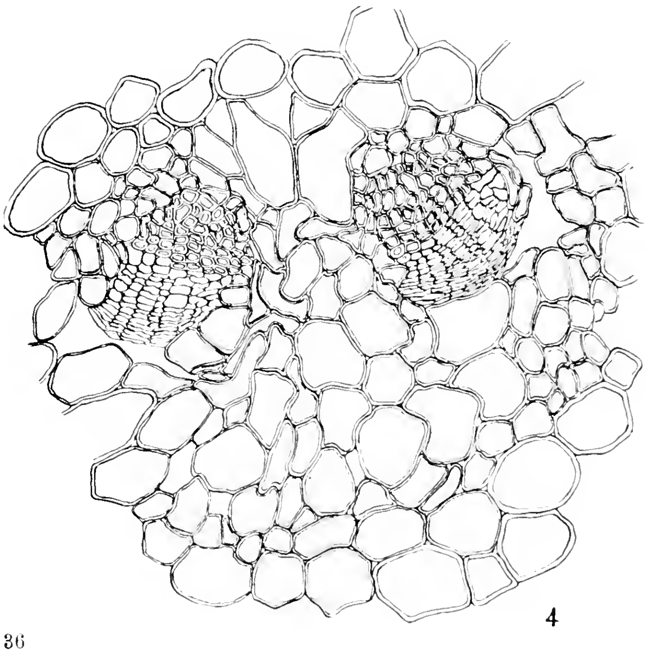


4

ABIES CONCOLOR Lindl. and Gord. White Fir.

Leaves flat, straight, 2 to 3 inches long.

Resin ducts ventral, touching epidermis; lined with 2 layers of cells; not lignified, except where ducts touch epidermal wall.

Vascular bundles very far apart, cells between lignified, no trace of a bundle sheath.

Hypodermal cells present on lateral edges and on lower side of leaf between bands of stomata.

Guard cells and heavy cells in epidermis above them lignified.

Stomata in 6 to 7 rows each side of midrib above, in
5 to 6 rows each side of midrib below.

Material from Campus of Iowa State College and from Jamaica Plains, Massachusetts.

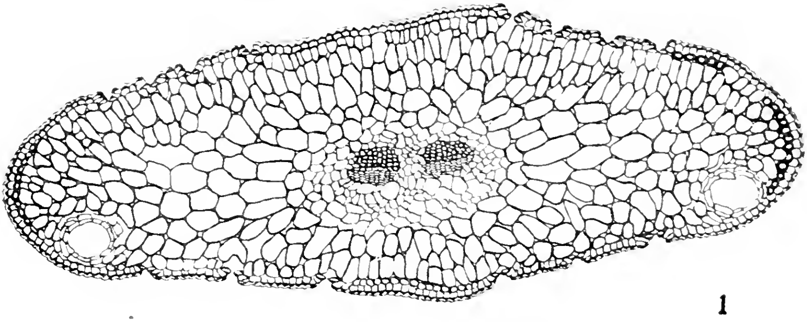
Plate LIX.

Figure 1.—Section of leaf of *Abies concolor*.

Figure 2.—Section through epidermis and stoma of leaf of *A. concolor*.

Figure 3.—Section through resin duct of leaf of *A. concolor*.

Figure 4.—Section through vascular cylinder of leaf of *A. concolor*.



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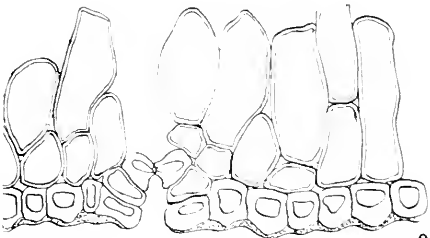

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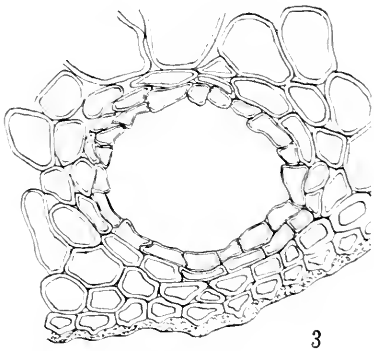

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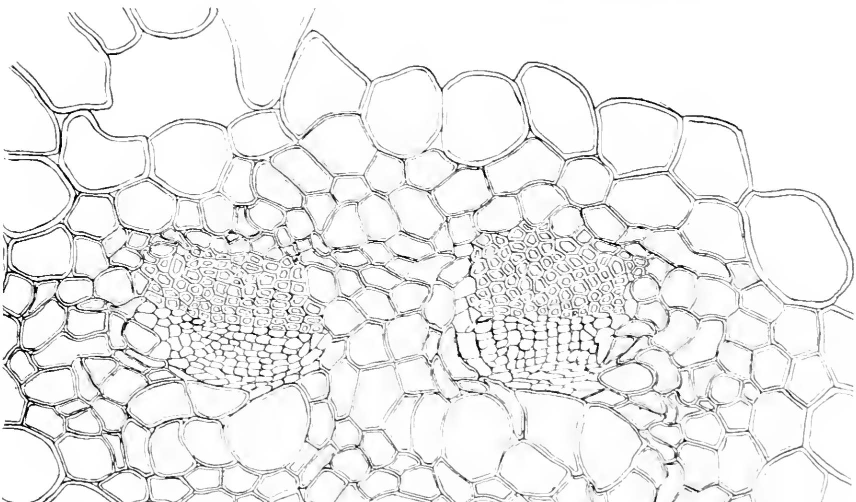


4

ABIES VENUSTA K. Kosh. Silver Fir.

Leaves flat, straight, lanceolate 1½—2¼ in. long, ⅛ in. wide.

Resin ducts small, ventral, touching epidermis, lined with 2 layers of thin walled cells.

Vascular bundles—surounded by a slight bundle sheath of loose, round cells; heavy walled irregular cells between bundles, lignified; phloem extending far around the sides of bundles.

Hypodermal cells present in double or triple layers below epidermis around entire periphery, except along stomata bands, strongly lignified; heavy layer of cutin over epidermis.

Stomata on lower surface only in bands of 8-16 rows each side of mid-rib.

Material from California.

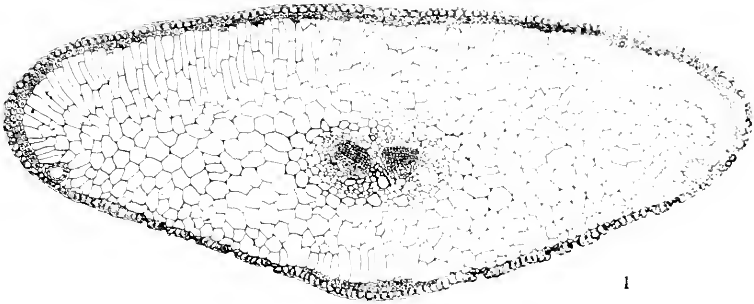
Plate LX.

Figure 1.—Section of leaf of *Abies venusta.*

Figure 2.—Section through lower epidermis and stoma of leaf of *Abies venusta.*

Figure 3.—Section through epidermis and resin duct of *Abies venusta.*

Figure 4.—Section through vascular cylinder of leaf of *Abies venusta.*



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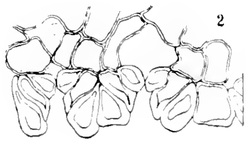

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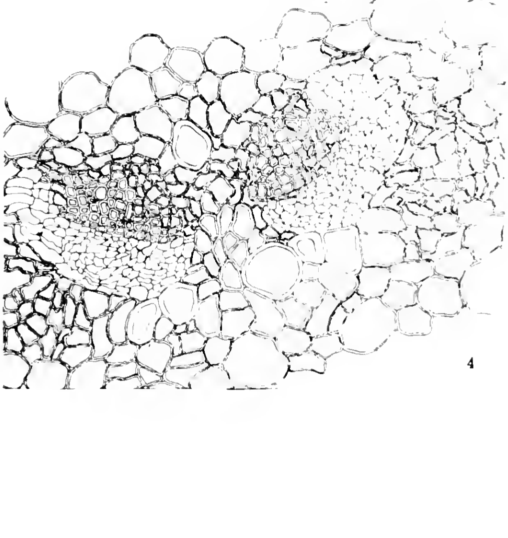


4

ABIES NOBILIS Lindl. Red Fir.

Leaves flat and deeply grooved above, on sterile branches; 4-angled on fertile shoots. 1/2 inch to 1 1/2 inches long.

Resin ducts lateral, touching ventral epidermis, lined with 2 layers of unlignified cells.

Vascular bundles surrounded by a bundle sheath of round, loosely joined cells: cells below phloem lignified.

Hypodermal cells present in lateral angles of leaf and along dorsal and ventral midribs in 1 to 2 layers, cells thick walled and lignified. In the 4-angled leaves they are more or less present around entire periphery.

Stomata present on both surfaces, 8 rows on upper surface and 10 rows on lower surface.

Material from Herbarium, Iowa State College.

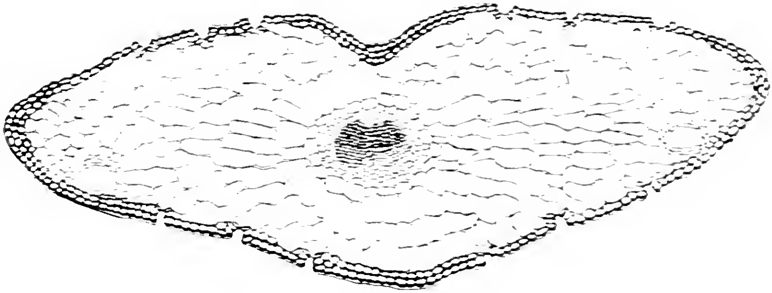
Plate LXI.

Figure 1.—Section of leaf of *Abies nobilis.*

Figure 2.—Section through epidermis and stoma of *A. nobilis.*

Figure 3.—Section through resin duct of leaf of *A. nobilis.*

Figure 4.—Section through vascular cylinder of leaf of *A. nobilis.*



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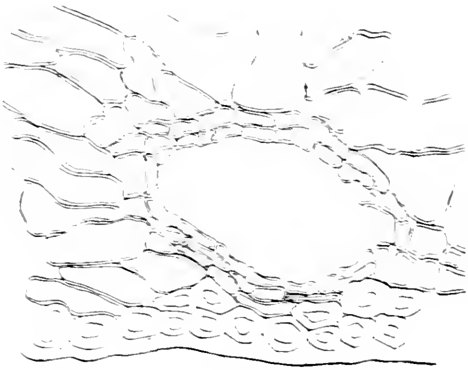

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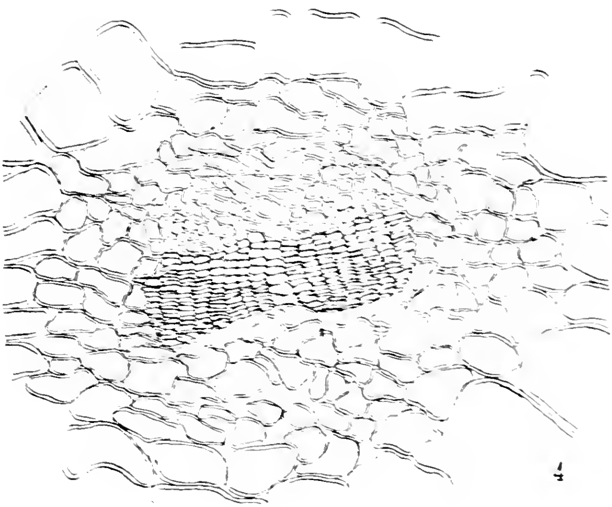


4

ABIES MAGNIFICA A. Murr. Red Fir.

Leaves 4-angled, ¾ inch to 1½ inches long.

Resin ducts, large, lateral, touching epidermis on ventral side, lined by 2 layers of unlignified cells.

Vascular bundles large and close together. Vascular cylinder not surrounded by a definite sheath; 2 large groups of lignified cells present each side of phloem.

Hypodermal cells thick walled and lignified, located in lateral angles, dorsal angles, and adjoining resin ducts, also scattered in groups of 2 and 3 along ventral side of leaf.

Stomata in bands of 6 to 8 rows on each of the four sides of the leaf.

Material from Jamaica Plains, Massachusetts.

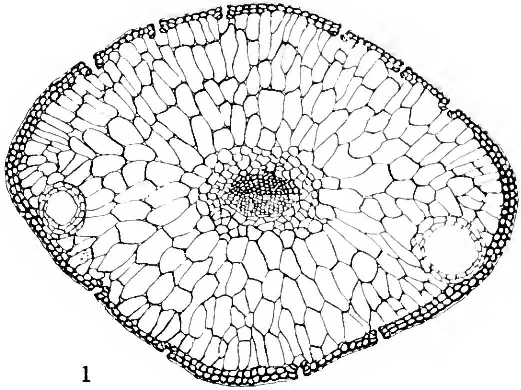
Plate LXII.

Figure 1.—Section of leaf of *Abies magnifica.*

Figure 2.—Section through epidermis and stoma of leaf of *A. magnifica.*

Figure 3.—Section through resin duct of leaf of *A. magnifica.*

Figure 4.—Section through vascular cylinder of leaf of *A. magnifica.*



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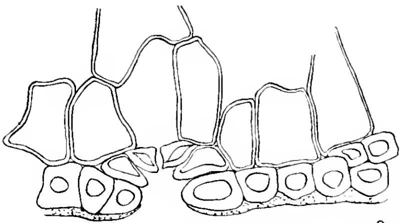

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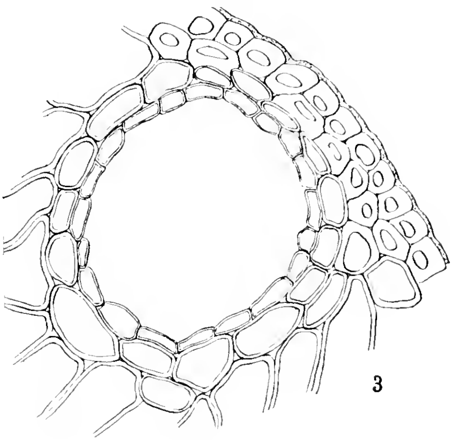

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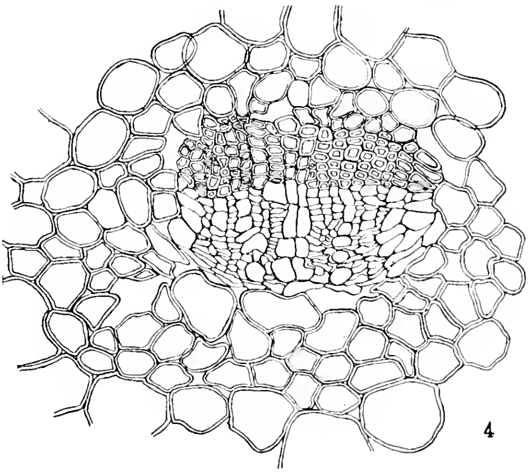


4

SEQUOIA SEMPERVIRENS Endl. Red Wood.

Leaves (secondary and lower branches) flat, lanceolate, 1/4 to 1/2 inch long.

Resin ducts 3, lined with unlignified cells.

Vascular bundle one. No bundle sheath. Cells adjoining bundle slightly lignified.

Hypodermal cells present along upper surface and extending around edges of leaf to resin ducts, lignified and thick walled.

Epidermal cells not lignified.

Stomata on dorsal surface in 2 narrow bands, ventral surface stomatiferous on each side of midrib.

Material from University of California.

Plate LXIII.

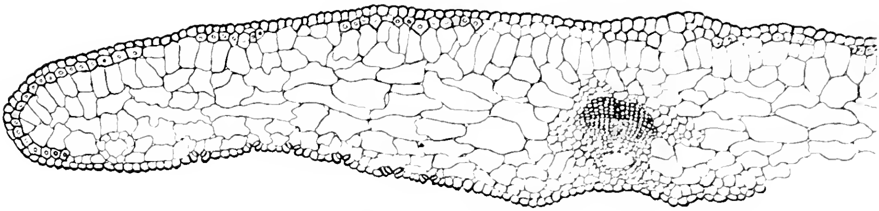
Figure 1.—Section of leaf of *Sequoia sempervirens.*

Figure 2.—Section through upper epidermis of leaf of *S. sempervirens.*

Figure 3.—Section through lateral resin ducts of leaf of *S. sempervirens.*

Figure 3 (lower).—Section showing stoma and underlying parenchyma of *S. sempervirens.*

Figure 4.—Section through vascular cylinder and central resin duct of leaf of *S. sempervirens.*



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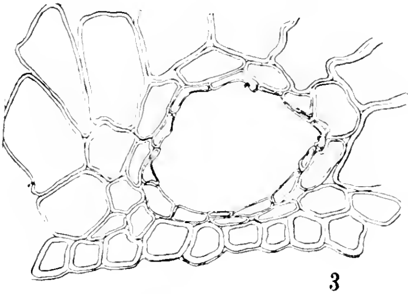

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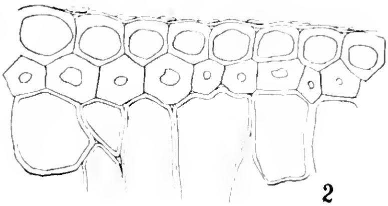

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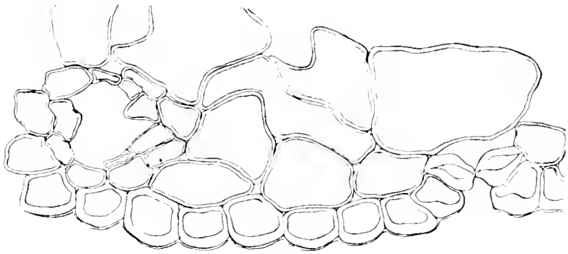

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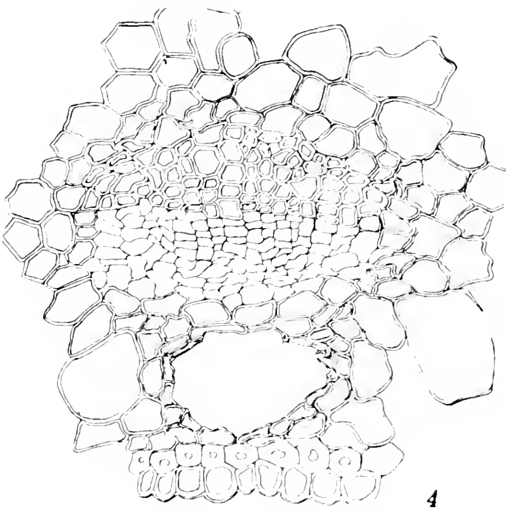


4

TAXODIUM DISTICHUM Rich. Bald Cypress.

Leaves small, 1/2 to 3/4 inch long, flat, notched on top.

Resin ducts not present.

Vascular bundles obscure. Xylem consists of 6 or more small lignified cells, the remainder of bundle composed of a group of small undifferentiated, round cells. At each side of bundle lie 3 to 4 large cells slightly lignified.

Hypodermal cells not present.

Epidermal cells not lignified.

Parenchyma walls corrugated.

Stomata on lower surface of leaf.

State House grounds, Sacramento, California.

Plate LXIV.

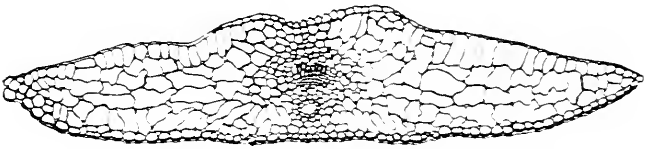
Figure 1.—Section of leaf of *Taxodium distichum* showing resin duct.

Figure 1'.—Section of the same showing a leaf not having resin duct.

Figure 2.—Section through lower epidermis and stoma of leaf of *T. distichum*.

Figure 2'.—Section through upper epidermis of same.

Figure 4.—Section through vascular cylinder and resin duct of leaf of *T. distichum*.



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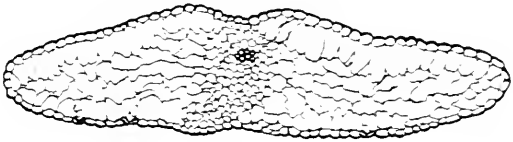

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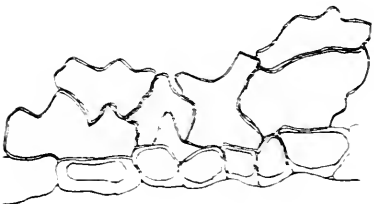

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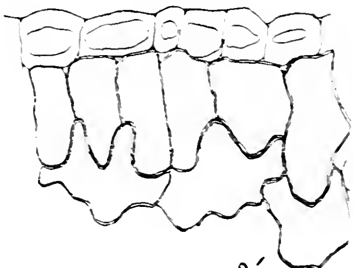

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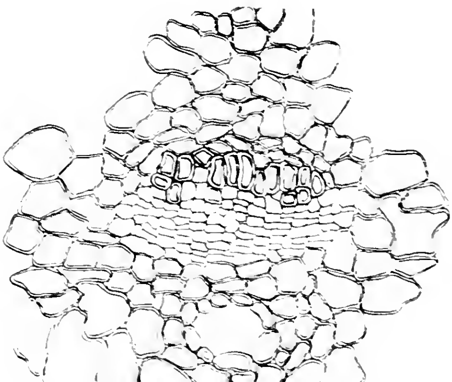


4

TUMION TAXIFOLIUM Green, Torreya. Stinking Cedar.

Leaves very broad and flat. $1\frac{1}{2}$ inches long, edges tending down.

Resin duct 1, large, ventral, central, below vascular bundle but not touching epidermis. Lined by several irregular concentric layers of cells.

Vascular bundle single, not enclosed in a sheath. Xylem bundle thin and crescent shaped, often a few strengthening fibers present at sides of phloem.

Hypodermal cells not present.

Epidermis shallow, heavy walled and lignified, lower epidermal cells slightly mammillated.

Stomata borne in 2 broad, shallow grooves on ventral side of leaf, one groove each side of midrib. Stomata flanked by long forked pillars, guard cells lignified.

Palisade parenchyma not very deep, composed of broader shallower cells than *Tumion californicum*.

Material from Tallahasse, Florida.

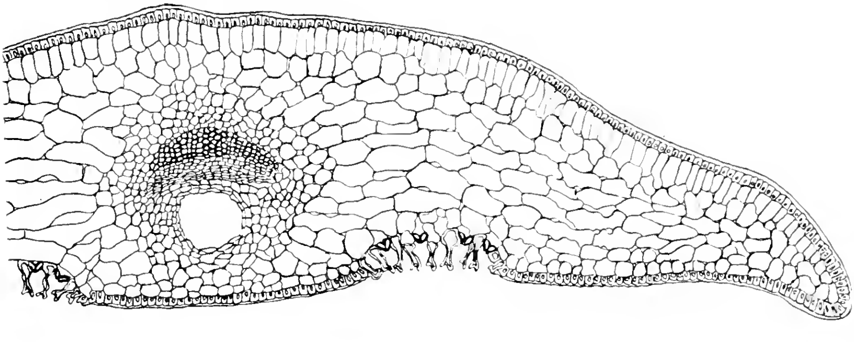
Plate LXV.

Figure 1.—Section of leaf of *Tumion taxifolium.*

Figure 2.—Section through a ventral groove, on leaf of *T. taxifolium,* showing stomata and pillar-like cells.

Figure 2′.—Section through epidermis of leaf of *T. taxifolium.*

Figure 4.—Section through vascular cylinder and resin duct of leaf of *T. taxifolium.*



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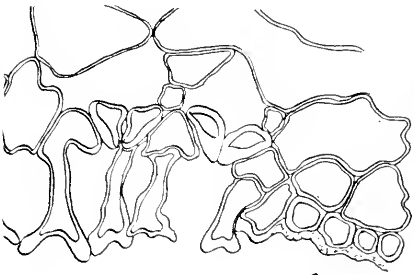

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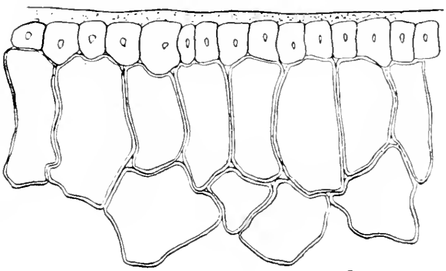

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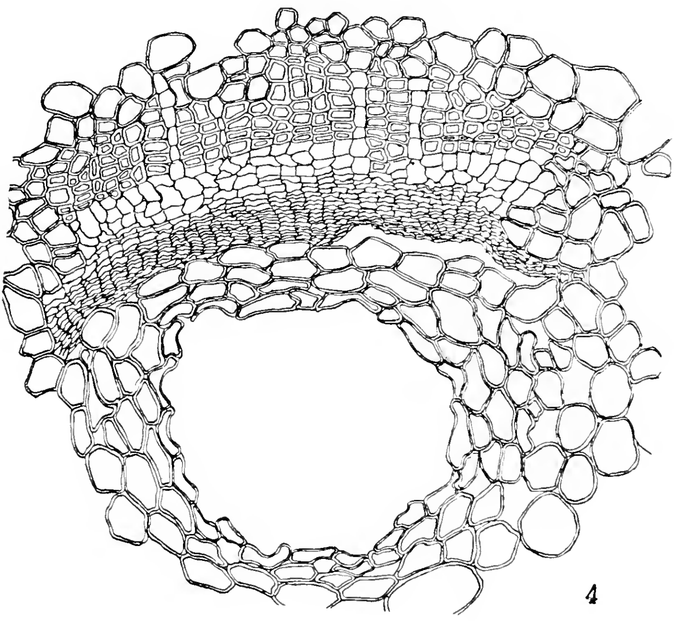


4

TUMION CALIFORNICUM Greene. California Nutmeg.

Leaves flat, 1 inch to 3½ inches long, edges tend down.

Resin duct one, large, central, on ventral side, not touching epidermis, lined by several irregular concentric layers of cells.

Vascular bundle one, not enclosed in a definite bundle sheath.

Hypodermal cells not present. Epidermis deep, very thick walled and lignified, lower epidermis decidely mammillated.

Stomata borne in deep narrow grooves on ventral side of leaf, one groove each side of midrib. Stomata flanked by long forked suberized pillars.

Palisade parenchyma very deep, composed of long narrow cells.

Material from University of California.

Plate LXVI.

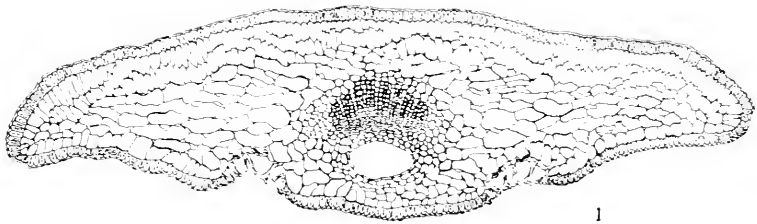
Figure 1. —Section of leaf of *Tumion californicum.*

Figure 2′.—Section through upper epidermis of leaf of *T. californicum.*

Figure 2″. —Section through lower epidermis of leaf of *T. californicum.*

Figure 2‴.—Section through a ventral groove on leaf of *T. californicum*, showing stomata and pillar-like cells.

Figure 4. —Section through vascular cylinder and resin duct of leaf of *T. californicum.*



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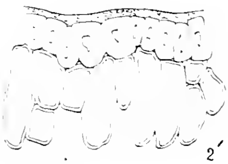

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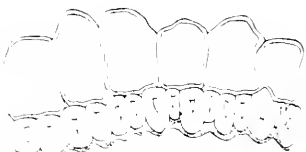

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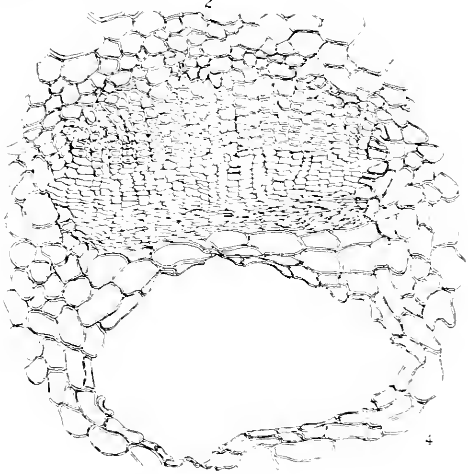


4

TAXUS BREVIFOLIA Nutt. Yew.

Leaves broad and flat, 1/2 to 5/8 inch long.

No resin ducts.

Vascular bundles not large, surrounded by a group of round, loosely joined cells; a group of lignified cells present in pith at each side of xylem band.

No hypodermal cells.

Epidermal cells very large and spherical, covered by a thick cutin, cutin deeply mammillated on lower side of leaf; guard cells lignified.

Palisade parenchyma not deep nor cells so narrow as in case of *Taxus floridana*.

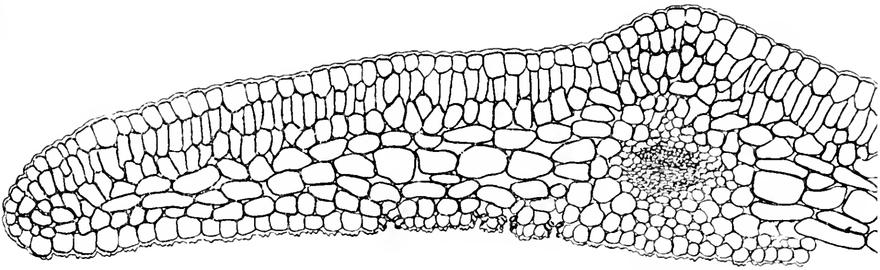
Material from University of Washington.

Plate LXVII.

Figure 1.—Sections of leaves of *Taxus brevifolia.*

Figure 2.—Section through lower epidermis and stoma of leaf of *T. brevifolia.*

Figure 4.—Section through vascular cylinder of leaf of *T. brevifolia.*



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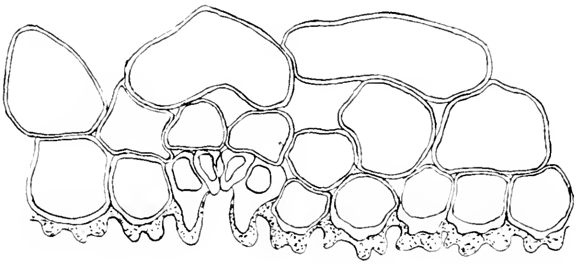

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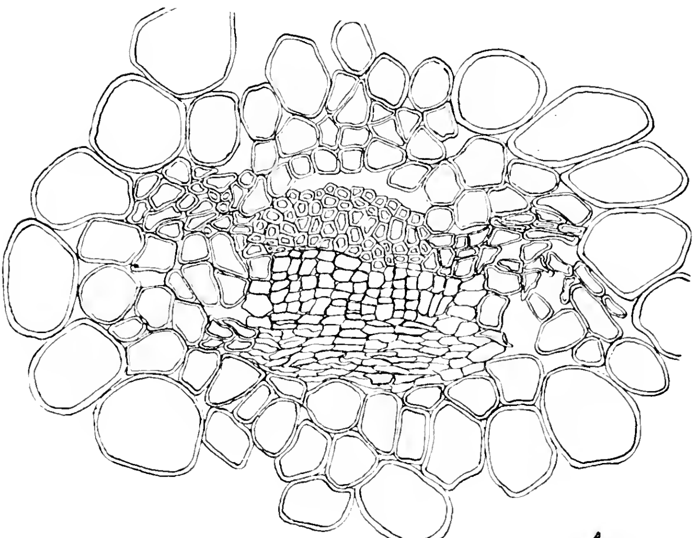


4

TAXUS FLORIDANA Chapm. Yew.

Leaves broad and flat, $^3/_4$ to 1 inch long.

Resin ducts none.

Vascular bundles large, not surrounded by a sheath but by a mass of loosely joined cells. Xylem in narrow band, lignified cells present in pith at each side of xylem.

Hypodermal cells not present.

Cells of epidermis flattened, smaller than in *Taxus brevifolia*, heavily cutinized, cutin deeply mammillated on lower surface; guard cells lignified.

Palisade parenchyma deep, composed of long narrow cells.

Material from State House grounds, Sacramento, California.

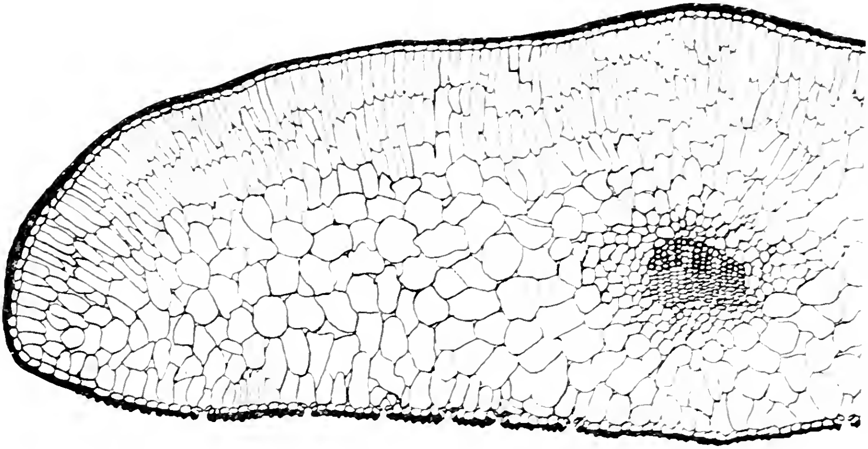
Plate LXVIII.

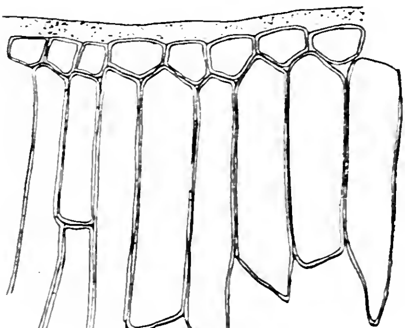
Upper figure.—Section of leaf of *Taxus floridana*.

Figure 2.—Section through upper epidermis and palisade parenchyma of leaf of *T. floridana*.

Figure 2′.—Section through lower epidermis of leaf of *T. floridana*.

Lower figure.—Section through vascular cylinder of leaf of *T. floridana*.





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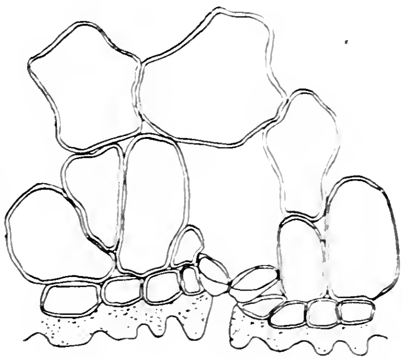

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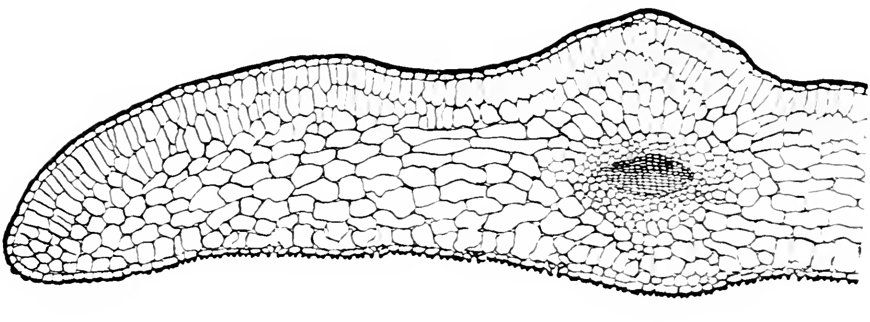

For assistance and advice in the above work acknowledgment is respectfully made to Dr. L. H. Pammel and Dr. J. N. Martin. For specimens used the writer is indebted to Dr. C. S. Sargent, Doctor Setchel, Mr. O. W. Newman, Dr. T. C. Fry, Prof. H. M. Hall, Mr. H. D. Petheram and Mr. E. Peck Greene.

LITERATURE CITED.

Sargent, Charles Sprague, Manual of the Trees of North America, pp. 35-101.

Engelmann, George, A Synopsis of the American Firs. Trans. Acad. Sci., St. Louis, III, pp. 593-602.

Bertrand, C. E., Anatomie des Gnetacee's et des Conifers. Ann. Sci. Nat. Bot., 20, 1874, pp. 5-153.

McNab, W. R., Remarks on the Structure of Leaves of Certain Coniferæ: Proc. Irish Acad., II, 1875, 209-213.

Sharp, Seymour S., Notes on the Determination of Rocky Mt. Conifers: Torreya, 15, No. 1, 1915.

Coulter, J. M., and Rose, J. N., Synopsis of American Pines, based on leaf anatomy: Bot. Gaz., Vol. II, 1886, 256-262 and 302-309.

Botanical Laboratory,
Iowa State College.

LATE POTATO BLIGHT EPIDEMICS IN IOWA AS CORRELATED WITH CLIMATIC CONDITIONS.

A. T. ERWIN.

At least three pronounced outbreaks of the late blight of the potato, *Phytophthora infestans*, have occurred in Iowa within the past forty-five years. These were in 1885[1], 1903, and 1915[2]. The northern limits of the region generally designated as the corn belt seems to represent in a general way the southern limits of this disease under normal climatic conditions. This is indicated by the fact of its frequent occurrence in the region just north of us.

From these regions of the north we receive our annual seed supply and this disease is therefore probably introduced into some portions of the state every year. The fact that under normal climatic conditions in Iowa it does not survive even when so introduced and yet in occasional years breaks forth in a virulent form, presents an interesting problem.

In many parts of the New England states late blight usually is an ever present disease and fails to develop only in dry years. In Iowa the conditions are reversed. It is normally absent and its presence in every known instance has been accompanied by abnormal weather conditions. This fact indicates an interrelationship between these outbreaks and the atmospheric conditions. In the following pages is presented a study of the correlations between climatic conditions and late blight epidemics in this state.

The relationship existing between many diseases and certain climatic factors is well known. It is usually difficult, however, to separate out the operative and nonoperative factors and to determine which are finally causative. The fact that in Iowa the outbreaks of this potato blight have always been accompanied by abnormal conditions permits of a careful study of its relation to those conditions and hence presents an approach to the

[1]The outbreak for 1885 was reported by Halsted, B. D. (Bot. Dept. Bull. Ia. Agrl. College, 95, Feb., 1888), and those for 1903 and 1915 came under the observations of the writer.

[2]Specimens for the years of 1903 and 1915 are filed in the Bot. Dept. herbarium of this institution and are identified by L. H. Pammel.

problem from a direction the reverse of that in the New England states, where considerable attention has been given to this disease.

Notable studies of late blight have been made under laboratory conditions, the most recent being those of Melhus[3]. These have contributed important information relative to the life history of the fungus and cleared away a number of erroneous conclusions based upon its supposed similarity to other mildews whose life histories were well known. Laboratory studies, however important, require confirmation under field conditions covering long periods of time and different sections of the country.

FIELD OBSERVATIONS IN IOWA.

In the following pages the writer has endeavored to supply these field data for Iowa conditions. It is particularly interesting to note the close parallelism between the actual conditions of the field and the findings of the laboratory, a fact which emphasizes the value of laboratory investigations for the correct interpretation of field data.

MOISTURE SUPPLY.

One of the vital factors affecting the growth of diseases is moisture supply. When present in excessive quantities, the plant growth is apt to be very succulent and sappy thus affording ideal feeding grounds for the parasite and these conditions also augment spore production.

The rainfall by months for the years of 1885, 1903, and 1915, is presented in the following table:

RAINFALL FOR IOWA.

YEAR	JUNE	JULY	AUGUST	TOTAL DEPARTURE FROM NORMAL	TOTAL PERCENTAGE EXCESS
Normal	4.38 in.	3.92 in.	2.91 in.		
1885	5.03 in.	6.55 in.	6.10 in.	—6.47 in.	52.05
1903	2.86 in.	4.83 in.	6.64 in.	—2.84 in.	22.85
1915	4.16 in.	8.32 in.	2.81 in.	—3.27 in.	26.30

It will be noted that the rainfall was deficient for June in two of these years. July and August were very wet for 1885,

[3]Melhus, I. E., Jour. Agrl. Res. V—2, Oct., 1915.

the total excess for the three months being 32 per cent. July and August of 1908 were also wet, the total excess amounting to 23 per cent.

July of 1915 was very wet, in fact with one exception the wettest July in the climatological history of the state. August of 1915 was dry but the total excess of rainfall for the three months was approximately 26 per cent.

Since there is a vital relationship between weather conditions covering the period of incubation and since that period also bears a direct relationship to the time of final outbreak or secondary period of infection, we have presented the rainfall data in the following table in ten-day periods which we shall call decades.

RAINFALL FOR SUMMER MONTHS OF 1905 BY DECADES IN INCHES.

(Des Moines station.)

		ACTUAL	NORMAL	DEPARTURE
JUNE:				
	First decade	.59	1.67	—1.08
	Second decade	1.56	1.72	— .16
	Third decade	.91	1.77	— .86
JULY:				
	First decade	1.57	1.24	— .33
	Second decade	.72	1.11	— .39
	Third decade	1.73	1.31	— .42
AUGUST:				
	First decade	2.68	1.00	—1.68
	Second decade	.23	1.48	—1.25
	Third decade	3.86	1.14	—2.72
	Total.............	13.45	12.48	— .97

In two instances, the first decade of June was wet and in one dry. The second decade of June in two of the years was dry and wet in one. The third decade of all three Junes was dry. These conditions point to the fact that an excess of moisture in June is not a requisite factor for the development of this disease and that even a normal June moisture supply is not necessary. In brief, the moisture supply for June would not seem to be a limiting factor for the development of late blight under Iowa conditions.

July for all three decades of the three years was with one exception wet. The third decade of July was in all instances very wet. The excess in two of them was quite pronounced. The conditions in this third decade of July are without doubt significant in relation to the outbreaks which occurred during this period in at least two of the epidemics. The decade in which the outbreak of 1885 occurred was not recorded, but judging from analagous climatic conditions it also occurred probably during the third decade of July and during early August.

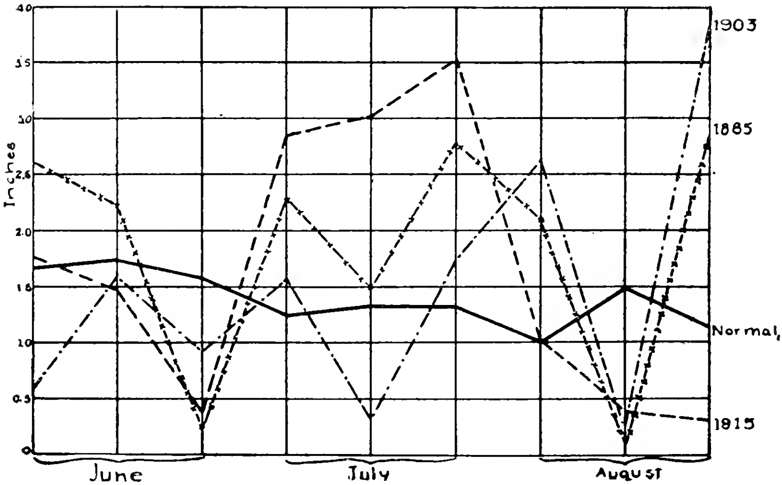

FIG. 49—Rainfall by decades of each month. Des Moines station.

The first decade of August was wet in all three years. This third of the month was also covered in at least two of these outbreaks by a period of secondary infection. The second decade of August was dry in all three instances. Since the vines were dead by this time, the atmospheric conditions for the second and third decade of August would not be significant in relation to foliage destruction.

HUMIDITY.

Humidity and rainfall are usually closely associated though such is not necessarily the case. From the standpoint of the host plant, rainfall is the more important factor while humidity bears a direct relationship to the growth and development of foliage diseases. A liberal supply of atmospheric vapor and dew combined with the right degree of temperature provides ideal conditions for spore production and germination. In the following table are presented the humidity data for the three years in question.

HUMIDITY TABLE.

(Des Moines Station.)

	June Per Cent	July Per Cent	August Per Cent	Total Percentage Departure From Normal
Normal	68.0	67.6	71.4	
1885	76.6	79.8	79.7	—29.1
1903	71.1	72.2	78.0	—14.3
1915	74.0	71.1	75.4	—19.5

It will be noted from this table that the humidity factor is much more constant than that of rainfall. In all of the months in all three years, the humidity runs abnormally high even in the months in which the rainfall was deficient.

The conditions with regard to humidity are more clearly brought out in relation to the different stages of the development of the disease when presented by decades.

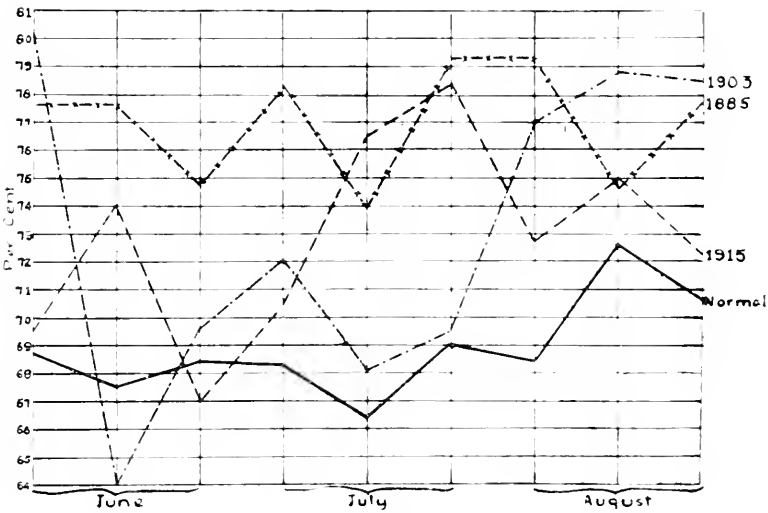

FIG. 50—Per cent of humidity by decades of each month. Des Moines station.

Without reviewing the decades of each month in detail, special attention is called to the high degree of humidity for the third decade of July in 1885 and 1915. For the year 1903, this high stage of humidity came a little later and was reached during the first decade of August.

TEMPERATURE.

Probably but few parasitic fungi are more sensitive to temperature conditions than late blight. Its occurrence in Iowa is dependent upon comparatively cool weather and in the cool climate of Maine upon comparatively warm weather. In both instances the thermal mean for the years of its recurrence is probably much the same. In one territory, its growth is limited by too low a normal and in the other by one too high.

The mean temperature in Iowa by months is given in the table below:

MEAN TEMPERATURES FOR IOWA.

	JUNE DEGREES F.	JULY DEGREES F.	AUGUST DEGREES F.	TOTAL DEPARTURE DEGREES F.	TOTAL PERCENTAGE DEPARTURE
Normal	69.1	74.1	71.8		
1885	69.0	75.9	68.7	—1.4	.65
1903	64.6	70.9	69.1	10.7	4.83
1915	65.1	69.5	65.9	14.5	6.74

1885. The temperature was .1° below normal for June and 3.1° deficient for August. July averaged 1.8° above normal.

1903. June—"The month just closed was the coldest June on record for the period of 14[*] years." The daily mean was 5.6° below normal. July—Daily mean 2° below normal. August—3.1° below normal.

1915. June—4° below normal. "The coldest June since 1903. At numerous stations the monthly mean and absolute maximum temperature for the month was lower than ever before recorded in June." July—"With one exception the coldest July of record." "August, 1915, was the coolest month of that name in the climatological history of the state. The monthly mean temperature and the monthly extremes were all lower than was ever before recorded and the daily means were below the normal means on all but four or five days during the month." Frost occurred in some part of Iowa in every month of the year 1915.

Taken as a whole, the years of outbreaks were distinctly cool seasons. Subnormal temperatures were very pronounced for

*The climatological data of this bulletin are based upon the records of the Iowa Weather Bureau. Thanks are due the director, G. M. Chappel.

the summers of 1903 and 1915. The same is true for 1885 with the exception of the third decade of July. During this decade the humidity, however, was above normal and gave one of the highest readings on record.

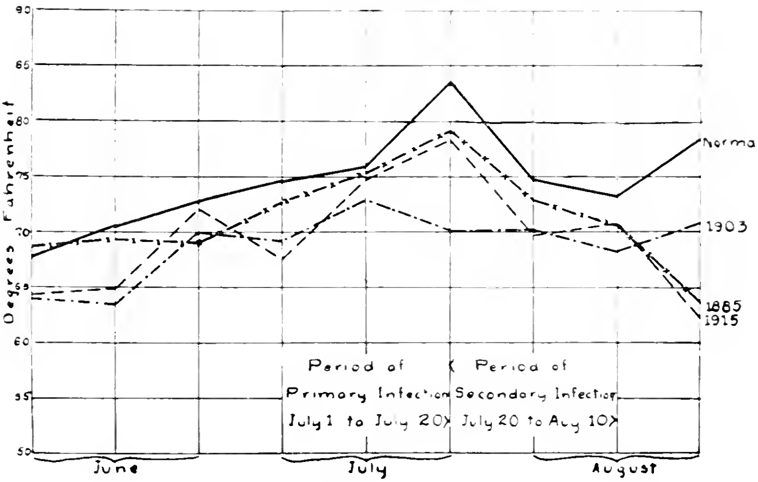

FIG. 51—Mean temperature by decades of each month. Des Moines station.

The deduction is clear that the normal mean temperatures for the summer months are too high for the development of late blight in Iowa and are limiting factors.

The exact optimum between the upper and lower temperatures at which this disease thrives under field conditions is difficult to determine. Selby[5] in laboratory tests found that temperatures ranging from 65° Fahrenheit to 75° Fahrenheit produced favorable conditions for the disease and Galloway states that "A normal temperature of from 72° Fahrenheit to 74° Fahrenheit accompanied for any considerable time by moist weather furnishes the best conditions for the spread of the disease."

Since the normal mean in Iowa for July is 74.1° Fahrenheit and for August 71.8° Fahrenheit and as the disease has occurred here only in the seasons of subnormal temperature during these months, it would seem that the last named figures are perhaps high.

[5]Selby, A. D., Ohio Naturalist, Feb., 1907.

The average of the means for July and August for the three years in question is 70° Fahrenheit. This temperature would seem to represent the danger line. So far as the temperature conditions are a factor, a mean below 70° Fahrenheit for the latter part of July and early August provides favorable conditions for an outbreak of late blight. In this connection it is interesting to note the statement made by Smith[6] that "The critical districts (for late blight) would be along the line of 70° Fahrenheit."

Conversely, regions lying within a mean above 70°, which includes Iowa, would be but little affected. The study of its history in this state supports this conclusion.

Since the disease is always more or less present through the introduction of infected seed, there is always the probability of an outbreak at a mean temperature below 70° Fahrenheit provided the humidity factor is also favorable.

SOIL TEMPERATURES.

The initial growth of the mycelium in an infected tuber is probably largely a matter of temperature conditions as moisture is supplied directly by the tuber.

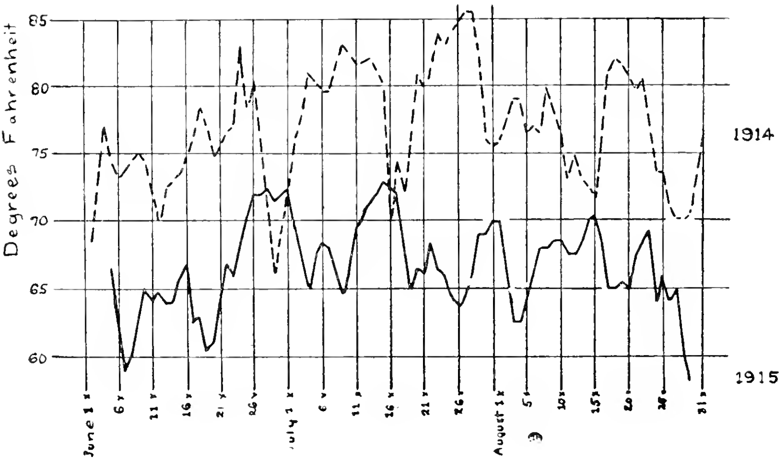

FIG. 52—Mean soil temperatures, Ames, Iowa. Readings taken at a depth of six inches.

The soil temperatures for the season of 1915 in comparison with those for 1914 are presented in the following table.

[6]Smith, J. W., Monthly Weather Review, 43-5-234, May, 1915.

These readings were taken in the experiment station potato field at a depth of six inches, which probably represents the main zone of tuber development for the potato. It will be noted that soil temperatures for 1915 are strikingly low as compared with 1914. It is to be regretted that this comparison cannot be made with a normal established over a long period of years. Orton[7] reports that in the outbreak of 1893 in Pennsylvania, the soil temperatures for the summer were notably low, and suggests that the soil temperatures are probably the primary factor in developing an epidemic. It is readily conceivable that the soil temperature is a limiting factor in the initial growth of the mycelium. However, once it reaches the foliage and sporulation begins the controlling factors would seem to be atmospheric rather than those of the soil. In fact, the study of our field conditions leads to the suggestion that through the planting of new seed the disease frequently makes a start but fails to sporulate due to unfavorable atmospheric conditions. Being unable to propagate it quickly perishes.

Through the courtesy of Professor J. G. Mosier of the Illinois Experiment Station we have the soil temperature records for the year 1915 in comparison with a normal, covering a ten year period at that station.

SOIL TEMPERATURES AT A DEPTH OF THREE INCHES.

(*Champaign, Illinois.*)

1915	Actual Degrees F.	Normal Degrees F.	Degree Departure	Percentage Departure
June	71.13	72.00	— .87	—1.21
July	74.06	75.80	— .74	— .98
August	70.23	75.80	—4.57	—6 03

In the following Sunshine Chart is shown the percentage of possible amount of sunshine for the years 1903 and 1915 as compared with the normal.

[7]Orton, C. R., Contributions from Dept. Bot. Pa. St. Coll., 1916.

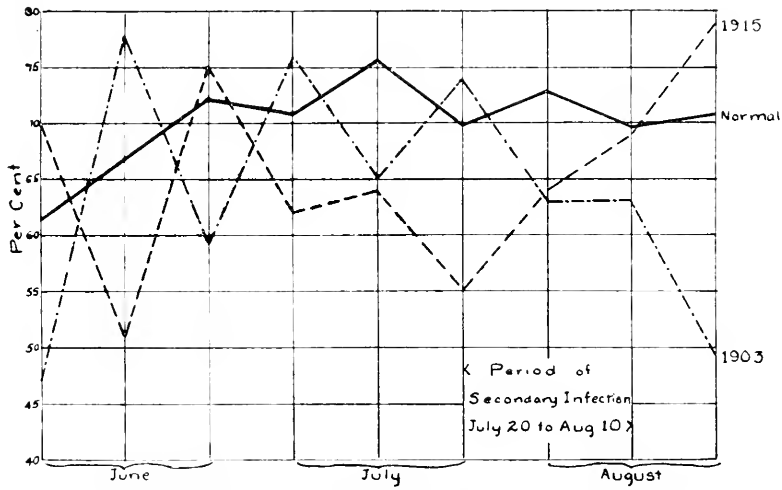

FIG. 53—Per cent of sunshine by decades of each month. Des Moines station.

Particular attention is called to the period covering the third decade of July and the first decade of August of this table in its relation to the period of secondary infection.

Unfortunately the sunshine records for 1885 are not available as they were not taken in this form by the Weather Bureau at that time.

As expressed in terms of clear, partly cloudy and cloudy days, the record for 1885 was as follows:

	CLEAR	PARTLY CLOUDY	CLOUDY
June	4	21	5
July	5	15	11
August	11	11	9

The germicidal properties of sunshine are well known. The delicate thin walled conidia are quickly destroyed by exposure to bright sunshine. The predominance of cloudy days was therefore an important aid in the propagation of the disease.

SUMMARY.

Climatic conditions in Iowa are generally unfavorable to the development of *Phytophthora infestans*.

The seasons in which it did occur were characterized by subnormal temperatures, high humidity, heavy dews, excessive rainfall and a predominance of cloudy weather.

IOWA AGRICULTURAL EXPERIMENT STATION.

THE FORMALIN TREATMENT FOR CONTROLLING OAT SMUT.

JOHN A. KRALL.

INTRODUCTION.

Five million dollars is a conservative estimate of the annual loss incurred by the oat smut disease in Iowa. That this loss can be controlled is indicated by the following statements from farmers over the state of Iowa.

Reports from 5,300 farmers representing over 15,000 acres of farming land, showed that 7.5 per cent of their oat crop was destroyed by this disease. On the other hand, reports from 654 farmers who had treated their seed oats showed that their loss was only 1.4 per cent.

To insure more definite knowledge of the control methods for oat smut, and to determine if possible a practical and efficient method for the farmer has been the purpose of our work. In the results which have been secured the writer wishes to acknowledge the co-operation and assistance which was accorded from time to time by Dr. L. H. Pammel, Prof. H. D. Hughes and others interested in the work.[1]

EARLY HISTORY OF OAT SMUT CONTROL MEASURES.

Selby (47) from review of early literature makes mention of two articles which are interesting from a historical standpoint. In the September 29th issue of the American Farmer, Baltimore, 1820, page 215, a correspondent tells of oats so badly smutted that the craddlers were nearly as black as colliers. The crop was allowed to lie on the ground for curing, in the old manner, and was turned after showers some four or five times before binding and gathering. The same oats sowed the next season gave a crop free from smut. The value of washing the grain no doubt was early recognized. In a later publication of the Cultivator, May, 1856, page 139, the editor recommends to one of his correspondents that "he wash the grain thoroughly

[1]This work was done in the botanical and farm crop laboratories Iowa State College.

in water, or still better, in brine (or giving the last washing in brine), and then rolling it well in dry powdered, water-slacked, fresh lime, some hours before sowing."

An article published in the Cultivator, 1837, Vol. 11, page 107, mentions a method which no doubt was in vogue at that time. The grain was soaked in a brine solution for twelve hours after which it was rolled in fresh slacked lime before sowing.

After 1856 the records indicate that copper sulphate was used to some degree with varying success. In 1887 and 1888 Jensen (29) published the results of his experiments with hot water—a method which still bears his name. Following the introduction of the Jensen method, Kellerman and Swingle (33) in 1889, published a rather complete treatise of the history and methods of control. As a result of their experiments potassium sulphide proved an efficient preventive. The treatment consisted in soaking the oats in a ¾ per cent solution of potassium sulphide (1½ lbs. of salt in 25 gallons of water) for a period of 24 hours. From this time on there is a noticeable interest in the oat smut problem. As a result sundry methods of control have been tried in an effort to secure one that would be convenient, efficient, and cheap. Of the many materials experimented with for the control of the smut disease the following have come to the attention of the writer. Kellerman and Swingle (33) have tried various combinations of copper sulphate, copper nitrate, potassium sulphate, mercuric chloride, potassium bichromate, sodium hyposulphate, sodium hydrogen carbonate, corrosive sublimate, chloroform vapors, carbon bisulphide, ether vapor, ammonium hydrate vapors, verdigris, sulphur, salicylicid acid, castile soap, hot water. L. H. Pammel (17) experimented with ammonical carbonate, ferrous sulphate, bordeaux mixture. By others, ceres pulver or powder, soap, tar dips and various other products have been tried.

Since it is the purpose of the writer to follow the history and the use of formalin for the control of the oat smut, other treatments will not receive consideration in this paper only as they have a bearing on the subject at hand.

Early History of Formalin.

Goff (25[a]) in his treatise on the use of formalin mentions that formalin was first discovered by a German scientist who had produced the gas from wood alcohol. Its germicidal properties seem first to have been discovered by Trillat in 1888. In 1895 Gruther published a paper stating that formalin was capable of destroying the germination of smut spores without injury to the grain.

The first use of formalin in the United States is credited to Professor Bolley of the North Dakota Station. After three years of investigational work the author made his first publication in March, 1897. During the same year Professor C. P. Close of the New York Station published the results of that season's experiments in Bulletin 131, 1897. During the next year Professor M. B. Thomas of the Indiana Station read a paper before the American Academy of Science regarding experiments with formalin. In this paper the author considers the effect of formalin on the germination of seed oats, and suggests that it might be well to try this substance upon the spores of smut as a possible prevention.

Arthur (1) in 1891 in his publication on loose smut of oats mentions the use of formalin. In this article the author states that various men have studied the action of this solution on seeds and spores but only in a subsidiary way. Its first application for the control of smut in a practical way is credited to Bolley. In the earlier publications of Bolley the writer failed to find any mention of the use of formalin. In his publication (6^b) on the treatment on wheat smut (1895) he mentions only the use of hot water, and copper sulphate, which had been in use for many years prior to that time. However, in a later publication (6^c), of 1897, he mentions the use of corrosive sublimate, sulphur dioxide, hot water, and formalin, and their effect upon the germination of wheat, oats, and barley. These experiments are quite extensive and are tabulated to show the effect of the treatment on the per cent of germination, the per cent of smut and the yield. The data are worthy of the attention of any investigator along similar lines of work. As a conclusion of his work Bolley sets forth the following treatment: "Thoroughly saturate a large pile of the grain with a solution made at the rate of one pound of formalin to 50 gallons of water. Shovel over rapidly so that the pile shall become evenly and thoroughly wet. In this treatment the grain should be left wet in the pile for two or more hours, or else dipped for two hours." The author also mentions the practical use of the solution and its cheapness ($1.20 per pound) as compared with potassium sulphide which would cost approximately $3.60 to treat 50 bushels.

In a later publication (6) 1910, the author reduces the water in the solution to 45 gallons. He also recommends that the grain should be soaked or covered for two hours after treatment. Two bushels of dry grain will equal approximately 2½ bushels after the treatment and due allowance should be made when seeding.

Arthur (1) in 1891 recommends, after reviewing the literature published by Bolley and after local experiments, that the formalin be used at the rate of one pound to 60 gallons of water. Immerse seed two hours or wet the pile thoroughly and let stand covered in a pile for two hours.

Goff (25) made first mention of the formalin treatment in 1901. After three years of experimenting on various treatments and methods of application the formalin treatment was considered efficient.

The following table shows the effect of the various formalin solutions on the growth of the plants under field conditions.

THE EFFECT OF VARIOUS FORMALIN SOLUTIONS ON THE GERMINATION, GROWTH AND YIELD OF OATS.

TABLE I. SHOWING AVERAGE HEIGHT OF PLANTS ON DIFFERENT DATES.

Treatment	Avg. Height in mm., May 14	Avg. Height in mm., May 22	Avg. Height in mm., July 30
Untreated	58.5	133.7	51.6
Formalin, 1 pint to 50 gal. of water.......	55.4	134.2	50.9
1 pint to 36 gal. water	63.8	138.7	52.6
1 pint to 25 gal. water	55.4	124.9	51.3
1 pint to 10 gal. water	26.2	80.7	54.7

TABLE II. WEIGHT OF PLANTS AT HARVEST.

Untreated	83.6 lbs.
Formalin, 1 pint to 50 gal. water......................	96.7 lbs.
Formalin, 1 pint to 36 gal. water......................	82.7 lbs.
Formalin, 1 pint to 25 gal. water......................	82.0 lbs.
Formalin, 1 pint to 10 gal. water......................	54.3 lbs.

The plots were seeded April 29th, a quantity of seed from each lot was planted on well prepared ground with a garden seed drill. The seed was sown thickly in rows fourteen inches apart and with a uniform depth of two inches. As the plants appeared they were thinned out so as to stand two inches apart in the rows except in the 1—10 treatment where the plants averaged eight inches apart, owing to lack of germination. On May 11th, and again on May 22d, the height in millimeters was determined on 500 plants in each lot. At harvest time the height of the plants was determined in inches.

TABLE III. EFFECT OF FORMALIN TREATMENTS ON YIELD.

Treatment	Amt. of Seed per Acre	Wt. of Entire Plant	Cleaned Grain Bu. per Acre
	lbs.	lbs.	
Untreated	70	520.5	68[illegible]
1 pt. to 50 gal....	70	575.0	$68\frac{5}{8}$
1 pt. to 36 gal....	70	399.0	$53\frac{3}{4}$
1 pt. to 25 gal....	70	484.0	$68\frac{1}{8}$
1 pt. to 10 gal....	70	165.0	$16\frac{7}{8}$

Note: The above plots were 1/40 acre in size. The seed was thoroughly dried before seeding, being seeded at the rate of 70 lbs. per acre with a garden drill. The drill rows were four inches apart and the grain seeded at a depth of two inches.

As a result of these field tests Goff concludes that under practical field culture the yield of grain is not appreciably affected by treating with a solution as strong as one pint of formalin to 36 gallons of water.

Clinton (12) 1895-1898, after comparing the relative value of hot water, formalin, copper sulphate, potassium sulphate, and ceres pulver, concludes that hot water and formalin proved most efficient.

TABLE IV. THE EFFECT OF FORMALIN ON THE PERCENTAGE OF SMUT.

Treatment	Smutted	Per cent Smutted
Formalin, 1 lb. to 25 gal. water...	Not a smutted panicle	0
Formalin, 1 lb. to 50 gal. water...	21 smutted on plot	0
Formalin, 1 lb. to 100 gal. water...	506 out of 4000	12.7
Untreated—check plot	440 out of 4000	11.0

For general use the author recommends the sprinkling method with formalin having a strength one pound to 40 to 50 gallons water. Sprinkle the grain at the rate of 1 to 2 gallons per bushel, thoroughly stirring the oats. The treated grain is then left in sacks for a few hours and then planted.

W. Saunders (45) in 1899 recommended the following formalin method: Soak the grain for one hour in a formalin solution made up to a strength of one pint formalin to 36 gallons of water. This treatment has been found equal to the copper sulphate solution consisting of one pound of copper sulphate to five gallons of water.

Wilcox (61) of the Montana Station (1899) states that oats treated with a solution of formalin (1 lb. to 50 gallons of water) and soaked for two hours were free from smut. This method is to be preferred to the copper sulphate treatment, which is injurious to the vitality of the seed.

Moore (37), 1901, after careful investigation, recommends the use of one pound of formalin to 36 gallons of water. Formalin with a guaranteed strength of 40 per cent. The method suggested is to immerse the oats in sacks for ten minutes, then place on a floor in a thin layer to encourage drying. The seed may be sown in one to two days, setting the drill to seed one bushel more than normally required.

Henderson (27) in his work at the Idaho Station in 1906 experimented with various formalin solutions to determine their effect on germination of wheat and oats. His conclusions are as follows: (Idaho Bulletin 53, page 107). "1. Seed treated with solution at strength of one pint of formalin to 16 gallons of water and covered for nearly one day, was injured but little. 2. Seed treated as above, and covered nearly two days was decidedly injured. 3. When treated with solution of one part to 50 gallons, one to 40 gallons, or even one to 25 gallons, the seed was not injured, though covered for two days. 4. When wheat has been treated in piles on the floor, do not cover at all, since germination is delayed, even though the grain is not injured. 5. When farmers complain of seed being injured it is the result of too strong a solution—(below 1-50 or 1-40) or to covering for too long a period—two or more days."

Mackey (41) of the Canadian Experiment Station at Indian Head makes first mention of the formalin treatment in 1898. At this time experiments were conducted to compare the relative value of formalin, bordeaux mixture, and copper sulphate solution. The solutions used were 3 ounces and 4½ ounces of formalin to 10 gallons of water. The oats were soaked for two hours in the formalin solution, while in the bordeaux and copper sulphate solutions the grain was steeped for four hours.

The result indicated that the formalin solutions were both efficacious—no disease being found in the resulting crop from the treated seed.

R. S. Shaw after three years' work at the Montana Station in 1903 (48) recommends a formalin solution consisting of one pint formalin to 40 gallons of water. Treat the grain either by dipping or sprinkling. In either case the gram should remain covered for two hours, after which it should be dried.

Shutt (49) in his report of 1906 remarks that the use of formalin for treating smut in cereals is increasing rapidly, due to its ease of application and effectiveness. Two strengths then in use were three and four ounces of formalin to 10 gallons of water. The grain was immersed for five minutes or sprinkled. In the majority of cases the weaker solution has proven as effective, and thorough sprinkling equal to immersion.

Stevens (52) in 1906 and 1907 conducted some extensive experiments to determine the influence of various formalin solutions on the germination of oats, especially when covered for different periods of time. Other experimenters have suggested strong solutions of formalin, but the effect on the vitality of the grain was often quite marked. The following table gives the results of the first series of experiments in which solutions of one ounce of formalin were used with one-half, one, two and three gallons of water.

EFFECT OF FORMALIN UPON GERMINATION.

TABLE V. SOLUTION OF DIFFERENT CONCENTRATIONS.

Strength, Amt. formalin Solution, Amt. of water	1 oz. 2½ gal.	1 oz. 1 gal.	1 oz. 2 gal.	1 oz. 3 gal.
	Per cent	Per cent	Per cent	Per cent
Covered 12 hrs. after treatment then seeded immediately	25	95	97	93
Seeded immediately after treating	47	99	88	89
Dried 48 hours before seeding	43	96	98	94
Covered 12 hours, dried with lime before seeding	35	94	94	96
Average	37	96	94	93

The author concludes that the strongest solution is decidedly injurious, either when seeded immediately or after covering 12 hours, as in either case the formalin was kept in contact with the seed much longer as compared with the other treatments. While it is apparent that the solution (one ounce to one gallon) had no apparent affect field tests have demonstrated that at times even this solution may cause a decreased stand.

The variability in results might be attributed to other causes, which raised the following questions:

Do different varieties of oats offer different degrees of resistance to formalin? What percentage of the seed is killed by formalin of the strengths usually employed? Does formalin have any stimulating affect upon germination? Are the seeds of inferior quality more susceptible than those of medium or excellent quality? Does the fatality increase with the increase of the time of application? While many tests have been made bearing upon these points, they have usually been made with only one or two factors in mind, and the results are neither concordant nor conclusive. In order to determine some of these factors a series of crucial experiments were planned with the hope of gaining conclusive answers.

In all cases 1,000 seeds of average quality were taken and treated for twelve hours. They were treated with formalin of the strength indicated and one cc. of the solution was employed to 9.3 cc. of seeds, this being equivalent to the usual practice of using one gallon of liquid to one bushel of seed. The seeds, after being thoroughly wetted by the solution, were placed in glass capsules, of suitable size, to prevent loss of formalin by evaporation. Great care was taken to have the lots exactly alike, except as regards the factor under observation. After treatment the seeds were planted in flats in clean sifted sand in rows one-half inch apart, with the seeds evenly distributed in the rows. In this manner, it was possible to account for every seed. The final record of germination was taken two weeks after planting, since experience showed that all available seeds germinated in that time.

All seeds designated as average quality were secured by discarding from a clean commercial sample of considerable size, all foreign seeds and empty chaff, but retaining all actual oat seeds, each of which, in case of any possible doubt, was inspected as to its integrity. This sample was thoroughly mixed and the 1,000 seeds for the test were taken absolutely without selection by always taking the seed lying nearest at hand, be it large or small. The strengths most used in practice, .26 per cent, .39 per cent, and .78 per cent of formalin, or as more commonly designated, one ounce to three gallons, one ounce to two gallons, and one ounce to one gallon, were employed; also a weaker solution, one ounce to four gallons (.2 per cent formalin). The first of these is mostly used, the second often, the third rarely.

Several varieties were used in this experiment to determine whether there was any noticeable difference in their ability to withstand certain treatments. These results are indicated in the following tables.

INFLUENCE OF DIFFERENT STRENGTHS UPON WHITE SPRING, RED RUST PROOF, VIRGINIA WINTER GRAY, APPLER, BURT, BLACK SPRING OATS OF AVERAGE QUALITY TREATED TWELVE HOURS.

TABLE VI. TEST OF THE WHITE SPRING OAT, 1,000 SEEDS.

Flat No.	Strength of Solution	Number Germinated	Per cent Germinated	Per cent due to Treatment
11	Control	998	99.8	..
14	1 ounce to 4 gal.[1]	996	99.6	.2
15	1 ounce to 3 gal.[2]	993	99.3	.5
13	1 ounce to 2 gal.[3]	985	98.5	1.3
12	1 ounce to 1 gal.[4]	941	94.1	5.7

[1] .2 per cent formalin, .08 per cent formaldehyde.
[2] .26 per cent formalin, .104 per cent formaldehyde.
[3] .39 per cent formalin, .156 per cent formaldehyde.
[4] .78 per cent formalin, .312 per cent formaldehyde.

TABLE VII. TEST OF RED RUST PROOF OAT, 1,000 SEEDS.

Flat No.	Strength of Solution	Number Germinated	Per cent Germinated	Per cent due to Treatment
16	Control	989	98.9	..
17	1 ounce to 4 gal.	984	98.4	.5
20	1 ounce to 3 gal.	984	98.4	.5
19	1 ounce to 2 gal.	973	97.3	1.6
18	1 ounce to 1 gal.	925	92.5	6.4

TABLE VIII. TEST OF VIRGINIA GRAY OAT, 1,000 SEEDS.

Flat No.	Strength of Solution	Number Germinated	Per cent Germinated	Per cent due to Treatment
30	Control	895	89.5	..
29	1 ounce to 4 gal.	883	88.3	.2
28	1 ounce to 3 gal.	855	88.5	.4
27	1 ounce to 2 gal.	821	82.1	7.4
26	1 ounce to 1 gal.	790	79.0	10.5

TABLE IX. TEST OF APPLER OAT, 1,000 SEEDS.

Flat No.	Strength of Solution	Number Germinated	Per cent Germinated	Per cent due to Treatment
10	Control	966	96.6	..
8	1 ounce to 4 gal.	977	97.7	1.1
9	1 ounce to 3 gal.	958	95.8	.8
7	1 ounce to 2 gal.	933	93.3	3.3
6	1 ounce to 1 gal.	912	91.2	5.4

TABLE X. TEST OF BURT OAT, 1,000 SEEDS.

Flat No.	Strength of Solution	Number Germinated	Per cent Germinated	Per cent due to Treatment
1	Control	903	90.3	..
2	1 ounce to 4 gal.	922	92.2	1.9
3	1 ounce to 3 gal.	930	93.0	2.7
4	1 ounce to 2 gal.	901	90.1	.2
5	1 ounce to 1 gal.	730	73.0	17.5

TABLE XI. TEST OF BLACK SPRING OAT, 1,000 SEEDS.

Flat No.	Strength of Solution	Number Germinated	Per cent Germinated	Per cent due to Treatment
25	Control	934	93.4	..
24	1 ounce to 4 gal.	959	95.9	2.5
23	1 ounce to 3 gal.	949	94.9	1.5
22	1 ounce to 2 gal.	903	90.3	3.1
21	1 ounce to 1 gal.	911	91.	2.3

In the foregoing test the White Spring, Red Rust Proof and Virginia Gray oats gave perfectly consistent results, showing decreased germination with an increase in the strength of the solution employed, the loss ranging from .2 to 5.7 per cent with the White Spring Oat and from .2 to 10.5 per cent with the Virginia Gray oat. The Burt oat and the Black Spring oat (Tables X and XI) show some inconsistencies in the test. However, it seems evident that the Burt oat is more susceptible to the strongest solution.

The conclusion may be drawn that solutions stronger than one ounce of formalin to three gallons of water are questionable, due to their appreciable effect upon the vitality of the oat. The added stimulus is offset by the loss of stand.

Stevens also worked on the effect of formalin solution on seed oats which varied in quality. In these experiments four kinds of seed were used. The grain was examined individually and divided into three classes: the largest and plumpest were designated as "good"; the next grade as lower or "medium"; and the smaller shrunken ones as "poor"; the average was the sample as found. In each instance 1,000 grains were used for each grade. All grades were treated with the same solution, namely one ounce of formalin to one gallon of water.

EFFECT OF QUALITY OF SEED ON RESISTANCE TO FORMALIN.

TABLE XII. APPLER OAT, 1,000 SEEDS.

Flat No.	Strength of Solution	Quality of Seed	Number Germinated	Per cent Germinated	Per cent Loss due to Treatment
10	Control	Average	966	96.6	5.4
6	1 ounce to 1 gal.	Average	912	91.2	
45	Control	Good	991	99.1	3.7
46	1 ounce to 1 gal.	Good	954	95.4	
43	Control	Medium	976	97.6	
47	1 ounce to 1 gal.	Medium	920	92.0	4.6
44	Control	Poor	937	93.7	
48	1 ounce to 1 gal.	Poor	780	78.0	15.7

TABLE XIII. VIRGINIA GRAY OAT, 1,000 SEEDS.

Flat No.	Strength of Solution	Quality of Seed	Number Germinated	Per cent Germinated	Per cent Loss due to Treatment
30	Control	Average	895	89.5	10.5
26	1 ounce to 1 gal.	Average	790	79.0	
36	Control	Good	924	92.4	
32	1 ounce to 1 gal.	Good	826	82.6	9.8
37	Control	Medium	909	90.9	
33	1 ounce to 1 gal.	Medium	801	80.1	10.8
38	Control	Poor	859	85.9	
34	1 ounce to 1 gal.	Poor	659	65.9	20.0

From tables XII and XIII it is evident that the poorer the grade of seed, the greater is the loss due to treating. Stevens suggests that the beneficial results often seen after certain treatments when the grain is seeded in the field is due to the destruction of the inferior seed. The averaged run of oats in the test indicates the presence of the inferior seed. If such results occur under all conditions it would seem advisable to grade and fan the seed oats prior to the treatment for smut.

For general use the solution of one pint to 48 gallons of water is recommended. The grain is either immersed for 20 minutes or sprinkled. Cover the grain for 6 to 12 hours. The oats may be readily dried by mixing with air slaked lime. The lime may be removed by a fanning mill. The seed may be stored after being thoroughly dried without affecting its vitality. In general one gallon of solution will treat one bushel of oats.

Willis (63), 1908, recommended in his treatments for oat smut a formalin solution with the strength of one pint to 25 gallons of water. The grain was to be submerged for 5 to 10 minutes and sown at once. This formula would treat 20 bushels of oats. The above mentioned solution is stronger than those recommended for general use by any experiment station today, yet it coincides with the results of our recent investigations. However, the author makes no mention of covering the oats for a period of time. Since the "time covered" element is regarded essential by many investigators the effectiveness of this treatment might be questioned.

Wilcox (62) suggests that the oats be immersed for 10 minutes in a formalin solution made up of one pint formalin to 30 to 40 gallons of water. After draining, cover the treated grain for two hours, after which spread the grain out to dry. when the sprinkling method is used the grain should be covered after treatment for several hours or over night. Dry the grain before seeding.

Bowman (7) recommended the sprinkling method using a solution "one pint formalin to 40 gallons of water," and one gallon of solution for each bushel of oats. Shovel the oats thoroughly, after which they should be covered for several hours. Spread out in a thin layer to dry.

E. M. Freeman and E. C. Stakman (20) used a formalin solution one pint to 40 to 50 gallons of water. The treated grain may be either immersed or sprinkled, after which it should be covered for 12 to 24 hours. The grain should be dried so that it can be run through a seeder.

Güssow (22) prefers the formalin treatment to that of copper sulphate since it does not affect the vitality to the same degree. The solution used consists of one pound or one pint of formalin to 40 imperial gallons of water. Either immerse or sprinkle the grain, then cover for two to three hours, after which it should be spread out to dry.

Various other statements in regard to the formalin treatment could be cited, but the foregoing are representative of all and give the history and range of variation occurring in the methods of treatment.

From the above citations it is evident that no standard method even with formalin has yet been secured. The solutions used ranged from one pint of formalin to 25 to 50 gallons of water. Various times for covering also are suggested, and this last factor is of considerable importance to the farmer. The advisability of seeding directly after covering and the amount of grain which should be used following such treatment are still open questions.

The Use of Vapor for Oat Smut.

Various experimenters have worked with different vapors in an effort to find some treatment which would eliminate the objections so apparent in the use of solutions.

Kellerman and Swingle (33) in their report of 1890 show that vapors of chloroform, carbon bisulphide, ether, ammonium hydrate, and sulphurous oxide were all ineffective. At that time formalin vapor was not used in their experiments.

Prior to 1899 Bolley had secured satisfctory results with the formalin solution (1 to 50). However, he recognized the objections that would be raised against any treatment which necessitated wetting the grain. In 1897 and 1898, Bolley ascertained that the gas treatment was effective, but was not positive of its use on a large scale. Following later experiments the author (6-87) concludes that for the gas to be effective it is necessary to have it accompanied by a vapor dense enough to form a film over the surface of every grain. The dry gas has no effect on the smut spores. The vapor factor again brings in the objection raised against solutions; however, the gas treatment is to be preferred for extensive work.

Clinton (1898) found that carbon bisulphide fumes were not effective, but work with stronger solutions of formalin applied in smaller amounts was very promising. In cases of too strong a solution the vitality of the grain was injured.

Wheeler (60) of the South Dakota Station (1904) conducted some preliminary experiments with various vapor treatments for stinking smut of wheat. These experiments included formaldehyde, ammonia and chloroform. The apparatus used for the gas treatment is described as follows:

It consists of a hand blower (a), a cylinder containing the grain (c), a test tube to contain the fungicide (b) and tubes for connection. The air is forced by means of the blower through the liquid fungicide in the test tube. From there it is conducted by a tube to the lower part of the cylinder containing the grain and up through the seed grain. The air permeated with the fungicide vapor is taken up from the cylinder by the blower and forced through the liquid fungicide. By repeatedly passing the same air through the fungicide, it was thought that a saturated atmosphere would be secured and greater uniformity of results obtained than if the air were passed only once through the fungicide.

The following treatments were considered in this preliminary work: The grain was exposed to the formaldehyde vapor (40 per cent solution) for the following periods of time ¼, ¾, 1½, 2, 2½, 3 hours, both with and without return current. (See tables XV and XVI.)

TABLE XV. FORMALDEHYDE VAPOR APPLIED WITHOUT RETURN CURRENT.

	Length of Treatment	Length of Row	Date of Seeding	Total No. of Heads	No. of Heads Smutted	Per cent of Heads Smutted
a	Untreated	20 ft.	Apr. 16	1,136	36	2.37
b	¼ hour	40 ft.	Apr. 16	2,303	31	1.35
c	½ hour	40 ft.	Apr. 16	2,245	26	1.16
d	¾ hour	40 ft.	Apr. 16	2,509	18	.72
e	1½ hours	40 ft.	Apr. 16	2,501	4	.16
f	2 hours	40 ft.	Apr. 16	2,570	17	.66
g	2½ hours	40 ft.	Apr. 16	2,791	19	.68
h	3 hours	40 ft.	Apr. 16	2,727	16	.59

TABLE XVI. FORMALDEHYDE VAPOR APPLIED WITH RETURN CURRENT.

	Length of Treatment	Length of Row	Date of Seeding	Total No. of Heads	No. of Heads Smutted	Per cent of Heads Smutted
a	¼ hour	40 ft.	Apr. 16	2,397	17	.7
b	½ hour	40 ft.	Apr. 16	2,397	6	.29
c	¾ hour	40 ft.	Apr. 16	2,638	5	.19
d	1 hour	40 ft.	Apr. 16	2,640	0	.00
e	1½ hours	40 ft.	Apr. 16	2,571	2	.08
f	2 hours	40 ft.	Apr. 16	2,407	1	.04
g	Untreated	40 ft.	Apr. 16	2,606	25	.96

Results of these trials indicate that the grain exposed to formaldehyde vapor without the return current was only slightly disinfected when compared with the check. The return vapor current at room temperature proved much more efficient as indicated by the declining percentage of smut in the treated plots.

It has been observed that temperature has more or less influence on the efficiency of formalin fumes. Some investigators recommend the use of warm water in the ordinary solution treatments.

Wheeler also conducted a series of experiments to determine this factor and its relation to the gas treatment. (See Table XVII.) Rossnau states that temperature is an important factor in disinfecting with formaldehyde. The gas condenses at 20 degrees C. to the solid polymeric paraform and disinfection should never be attempted if the temperature is under 10 degrees C. The action of the gas seems to be about the same between the temperature of 10 degrees C. and 27 degrees C.

TABLE XVII. FORMALDEHYDE VAPOR—EFFECT OF TEMPERATURE.

Temperature of Formaldehyde Solution	Strength of Solution	Length of Treat-ment	Date of Seed-ing	Length of Row	Total No. of Heads	Number of Heads Smutted.	Per Cent Heads Smutted.
a. 19° C.	40 p. c.	½ hr.	4/19	20 ft.	1,210	0	0.0
b. 20° C.	20 p. c.	½ hr.	4/19	20 ft.	1,263	0	0.0
c. 30° C.	40 p. c.	½ hr.	4/19	20 ft.	1,208	0	0.0
d. 60° C.	40 p. c.	½ hr.	4/19	20 ft.	1,280	0	0.0
e. 75° C.	40 p. c.	½ hr.	4/19	20 ft.	1,084	0	0.0
f. 19° C.	20 p. c.	3 hrs.	4/19	20 ft.	1,193	12	1.0
g.	5 p. c.	24 hrs.	4/19	20 ft.	1,319	3	.22
h. Untreated	......	......	4/19	20 ft.	1,074	13	1.24

In the above table (d) was raised to 60 degrees C. at the start and a second time after the treatment had been under way for five minutes. Treatment (e) was maintained at 75 degrees for five minutes. All others were simply started at the temperature designated. Some condensation took place on the grain under treatment (a) which may have injured the germination.

When the formaldehyde solution was heated the gas was much more effective. However, at the higher temperature 75 degrees C. for one-half hour a lowering of the germination was noticeable, due probably to condensing of the vapor on the grain. (See Table XVII.)

Further work with formalin vapor and formalin solution showed both to be ineffective in killing the spores within infected wheat grains. Other factors which may influence the results are mentioned, e. g., it was found that a 30 per cent solution of formaldehyde after air had passed through for two hours analyzed 38 per cent of formaldehyde. New chemicals should be used for each treatment to eliminate error.

TABLE XVIII. LENGTH OF GAS TREATMENT AND ITS EFFECT UPON GERMINATION.

Chemical Used	Length of Treatment	Per cent Germination 6 days after Sowing	Per cent Germination 7 days after Sowing	Per cent Germination 10 days after Sowing	Vigor of Growth, 10 equals Normal
Formaldehyde	1/3 hr.	79	85	90	10
Formaldehyde	2/3 hr.	72	76	81	10
Formaldehyde	1 hr.	65	75	80	10
Formaldehyde	1½ hr.	29	39	55	9
Formaldehyde	2 hr.	27	37	45	7
Formaldehyde	2½ hr.	21	23	24	7
Formaldehyde	3 hr.	26	31	33	7
Formaldehyde	4 hr.	18	22	24	7
Formaldehyde	5 hr.	15	20	23	7
None	......	75	83	84	10

The germination tests show that formaldehyde vapor from practically standard formalin solution can be applied to wheat for one hour without injury and is efficient in controlling the smut. (See Table XVIII.) Whether the above conclusions can be applied to the oat crops is still a question. The main problem is the feasibility of applying the treatment on a large scale for treating oats, which are of different structure and more bulky.

At present there is no satisfactory way of treating the grain with formaldehyde gas either on a large scale or on the farm. And since it is necessary to have the vapor at the point of saturation for efficient results, the solutions may as well be used for practical purposes.

EXPERIMENTS WITH VARIOUS FORMALIN SOLUTIONS AND THEIR RELATION TO THE GERMINATION AND CONTROL OF THE OAT SMUT.

AMES, IOWA, 1915.

At the present writing the formalin treatment seems to be the most efficient remedy for oat smut. However, it embodies one or more objectionable features from the standpoint of the practical farmer. These are, first, the time involved in treating; and second, the need of saturating the oat grain. While its efficiency is not questioned the still present objections may bear investigation.

Numerous experiments have been conducted with formalin, but as yet there is no uniformity in the results or recommendations. The solutions recommended vary from one pint of formalin to 25 to 50 gallons of water, the most common formula being one pint to 40 gallons. In addition recommendations include dipping and sprinkling of the solution, the grain to be either seeded directly or covered for various periods of time—from two to ten hours or more. To arrive at some definite and satisfactory method has been the purpose of this investigation. While one year's data are not conclusive it will indicate the possibilities of certain methods and act as a guide for further experimentation.

In these experiments twenty-two bushels of Kherson oats were used for the tests. Practically a half gallon of smut spores were thoroughly mixed with the oats to insure infection. However, it later developed that the spores were not as virile as was expected—the checks only showed an average of 1.83 per cent smut. One-half bushel, by measure, of the infected oats were used for each test. The container used in treating the oats was a large galvanized iron pan five inches deep and four by five and one-half feet in area. This was large enough to permit spreading and shovelling the oats. The container was cleaned out after each treatment.

After treating the oats were removed and piled on a muslin sheet about six feet square, the ends of which were pulled over the pile and tucked in around the base thus providing a good cover. Each pile was tagged stating the nature of the treatment, the time, and the various periods at which samples should be secured for a germination test.

About one pound of oats from each treatment were used for the germination test. In each instance the sample was secured from the center of the pile. These were taken at stated periods—time of treatment; end of first and second hours; and thereafter in two-hour periods, up to twelve hours. The sample was placed upon a clean table until dry, then sacked in a paper bag, after which it was stored for a period of one and one-half weeks, when germination tests were made.

In the germination tests duplicates were run in every case and the average of the two was recorded. Should the duplicate vary to any marked degree a new test was made of the sample.

Each test was on the basis of 200 kernels. The rag doll method was used, since a large number of tests could be taken care of in a rather small space. When the rag doll method is used it is advisable to place the oats on folds of the cloth arranged in successive tiers. It is essential that aeration is not retarded. In most cases the tests were ready to read within six days. Some of the readings indicate a marked variation even in the same series. Inconsistent tests were checked over again, but in some cases the results did not improve the average of the readings. The cause could not be determined in every case, which was illustrated by good and poor readings alternating in the same tester under identical conditions. The rag doll method is not as accurate as a good commercial tester, unless it is given careful observation.

The field plots used were 1-5 of an acre in size. With the exception of 45 plots in the series of 290, they were all the same shape, being 3x33½ feet. The soil was not as uniform as would be desirable; neither was the seed bed in as fine shape as it should have been owing to variable climatic conditions and lack of horse power. The resulting yields were, no doubt, influenced and will have to be discounted to a slight degree, since variations occur which can not be attributed to the treatments.

The plots were seeded April 10th and 11th, the grain being planted by hand in furrows one inch deep made with a hand marker. The rate of seeding was three bushels per acre, the grain having been previously weighed out for each row, placed in an envelope, and labelled. As the season progressed weed growth was kept down by frequent hoeings.

Harvesting was done by hand. The crop from each plot was shocked and labeled. At threshing time each plot was threshed separately in a small nursery thresher and the weight of the grain secured.

Results of the germination tests, based upon tables XIX and XX.

Conclusions to be drawn from Table XX—showing the effect of various formalin solutions and time of covering on the germination of oats. For each grade of solution the amount used per bushel of oats ranged from 1, 2, 4, 6 and 8 pints and the treated oats were then covered up for 0, 1, 2, 4, 6, 8, 10 and 12 hours respectively.

A. Solution—one pint formalin to three gallons of water.

1. While the germination tests do not seem to be consistent there is a gradual decrease in vitality as the amount used is increased from one pint to eight pints, and as the time of covering increases from none to twelve hours.
2. One pint per bushel may be used with comparative safety.
3. Two pints apparently affects the vitality. Larger amounts seem to have a decided affect upon the germination and should not be used.
4. Field tests showed that all the oats receiving 4, 6, and 8 pints per bushel were killed, except the first two of the 4-pint treatment. The zero and 1-hour covered seed evidently recovered from the effect of the treatment.

GERMINATION TEST OF OATS.

TABLE XIX. FOLLOWING TREATMENT WITH VARIOUS KINDS OF FORMALIN SOLUTIONS.

Solution	Pints per Bu.	Hours Covered							
		0	1	2	4	6	8	10	12
		Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
1 pint formalin to 3 gal. of water A	1	100	96	99	96	91	87	91	89
	2	85	92	93	91	82	83	87	86
	4	89	66	30	9	23	7	8	4
	6	6	23	1	0	0	0	0	0
	8	1	4	0	0	0	0	0	0
1 pint to 5 gal. B	1	96	97	91	96	96	98	98	96
	2	91	98	96	96	94	96	85	91
	4	96	98	61	79	38	54	32	31
	6	76	76	63	8	0	0	0	0
	8	19	11	1	0	0	0	0	0
1 pint to 10 gal. C	1	98	98	98	98	98	98	100	99
	2	94	90	94	95	97	94	96	96
	4	93	96	89	93	94	91	88	89
	6	99	81	91	83	83	94	94	95
	8	86	87	84	86	66	57	47	53
1 pint to 20 gal. D	1	96	96	95	94	90	94	95	92
	2	96	98	95	94	92	93	91	93
	4	96	94	95	93	91	91	90	92
	6	95	95	91	95	94	92	94	96
	8	98	96	94	98	91	96	95	95

Solution	Pints Per Bu.	Hours Covered							
		0	1	2	4	6	8	10	12
		Per Cent	Per Cant	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
1 pint to 30 gal. E	1	94	99	97	94	94	97	98	98
	2	77	97	92	97	97	97	95	97
	4	98	98	92	89	95	90	93	93
	6	98	93	92	91	93	96	96	93
	8	98	96	94	97	92	97	97	98
1 pint to 40 gal. F	1	93	90	97	94	98	99	96	97
	2	95	98	95	97	97	95	94	98
	4	97	99	97	98	98	96	92	..
	6	96	98	97	98	96	95	94	96
	8	98	97	98	97	95	95	93	95

Average of checks 95 per cent.

B. Solution—One pint formalin to five gallons of water.

1. One pint per bushel is safe for any of the hours covered.
2. When two pints are used there is a slight decrease in the vitality when covered for six or more hours.
3. Four pints may be used with safety when covered not to exceed one hour.
4. Larger applications and continuous covering lower the percentage of germination to zero, especially after the second or fourth hour of covering.
5. Field tests showed that all plots were below the average of the checks.

The plots seeded with the grain treated with six pints and covered zero and one hour germinated a little slowly, showing a decrease in stand of 50 to 60 per cent. However, at harvest time the yield was practically normal. Those plots seeded with the other treatments of the six and eight pints failed to germinate except occasionally could be seen a stray plant that had survived.

C. Solution—One pint formalin to ten gallons of water.

1. Germination tests indicate that one pint per bushel may be covered for a period of twelve hours without any apparent injury.

2. Two pints per bushel did not affect the vitality unless it be at the end of ten to twelve hours.

3. An application of four pints was followed by a slight decrease in germination when covered eight or more hours.

4. When six pints per bushel were used, there was an apparent decline in the germination from one to six hours, after which the germination seemed to improve. This may be due to the drying out of the oats and consequently the lessening effect of the formalin. Apparently there is some experimental error incurred when dealing in quantities smaller than several bushels.

5. Eight pints caused a gradual decrease in the germination for each hour covered. Covering for more than one hour is questionable.

6. Field tests showed that as the treatments per bushel increased there was a slight irregularity in germination, especially for those covered for several hours. No apparent accelerated germination was noted due to stronger treatments, as has been observed with the hot water treatment.

D. Solution—One pint formalin to twenty gallons of water.

1. The results of the germination tests indicate that a solution of this strength has no decided effect upon the vitality, even when covered for twelve hours.

2. In the field work there were no apparent differences in the plots seeded with the treatments of one and two pints per bushel.

3. When four pints were used and covered for eight hours, there was delayed heading of one day. When covered ten to twelve hours the heading was delayed at least two days.

4. The same effect was observed with the six pint treatment; however, the variation was more pronounced.

5. When eight pints were used, those treatments covering eight to twelve hours showed a lack of uniformity and also a decrease in the yield. How-

ever, as was previously mentioned, the yields are not a reliable criterion in such short term experiments.

E. Solution—One pint formalin to thirty gallons of water.

1. From the germination tests all treatments are safe.

2. In the field work the low yield assigned to a part of the plots was due largely to lodging prior to ripening. Otherwise, no particular difference was observed between these plots and the checks.

F. Solution—One pint formalin to forty gallons of water.

1. The vitality of the oats was not injured by any of the treatments.

2. The field records show that the crop yielded somewhat better than the checks. This is partly accounted for in that the soil in a portion of the series had received a heavier dressing of manure two years previous. No increased yields should be ascribed to the treatments.

Notes on Amount of Solution per Bushel.

1. When one pint per bushel was used, considerable handling made the oats damp but not wet. They were ready to plant after the treatment. Oats were practically dry at the end of twelve hours.

2. Two pints per bushel moistened the oats, but did not wet them to any marked degree. The oats were ready to seed after the treatment and were dry at the end of twelve hours.

3. With four pints per bushel the oats seemed to be covered with a film of solution, but there was no excess solution left after a thorough shovelling. The oats swelled considerably. At the end of twelve hours the pile was only slightly damp.

4. Six pints made the oats very wet, only a comparatively small amount of solution was left over after a thorough mixing.

5. Eight pints caused the oats to drip, a small amount of solution remaining after the oats were well mixed; evidently being more than could be taken up by the oats.

RESULTS OF GERMINATION TESTS OF GRAIN IMMERSED FROM ONE TO FOURTEEN MINUTES IN THE VARIOUS FORMALIN SOLUTIONS.

TABLE XX. GERMINATION OF IMMERSED GRAIN.

Solution		Time Immersed in Minutes			
Formalin Pints	Water Gallons	1 S. W. D.	2 S. W. D.	3 S. W. D.	4 S. W. D.
1	5	4— 6— 90	2— 2— 96	0— 0—100	0— 0—100
1	10	25—25— 50	23—21— 56	16—22— 62	2— 6— 92
1	15	55—13— 32	58—14— 28	39—22— 39	46—11— 43
1	20	70—14— 16	70—12— 18	66—12— 22	69—14— 17
1	30	93— 4— 3	93— 5— 2	94— 4— 2	95— 3— 2
1	40	93— 4— 3	95— 3— 2	92— 4— 4	93— 3— 4

TABLE XX.—CONTINUED.

Solution		Time Immersed in Minutes			
Formalin Pints	Water Gallons	8 S. W. D.	10 S. W. D.	12 S. W. D.	14 S. W. D.
1	5	0— 0—100	0— 0—100	0— 0—100	0— 0—100
1	10	1— 5— 98	0— 2— 98	0— 0—100	0— 0—100
1	15	32— 9— 59	9—12— 79	10—11— 79	10—12— 78
1	20	69—11— 20	68—12— 22	38—45— 17	53—15— 32
1	30	90— 6— 4	91— 6— 3	89— 6— 5	85—10— 5
1	40	93— 3— 4	93— 3— 4	89— 7— 4	92— 3— 5

Note: The symbols S. W. D. stand for strong, weak and dead.

It will be noted from the above table that the stronger solutions have a marked influence on the vitality of the oats. For all solutions below one to thirty the danger resulting from immersing is apparent. Even immersing for one minute in those solutions caused more injury than the use of eight pints per bushel of the one to ten solution and covering for two hours. Dipping grain in the solution of one to thirty and one to forty caused no apparent injury, and for practical purposes these may be recommended.

Effects of Various Treatments upon the Smut.

In the field tests the grain was seeded on April 10th and 11th. Heading was completed between the dates of June 22d and 26th, and the grain was all ripe July 16th to 18th. Harvest was finished by July 20th. Notes on the percentage of smut were taken at full heading. A two-foot division board was used for spacing the plants while counting. Six counts were made on each plot. The division stick was inserted at given intervals on a number of check plots. In this manner thirty-one checks were counted and the resulting average used for the compilations. There was an average of 105 panicle-bearing stems in the two-foot space. Only an average of 1.83 per cent of smut was noted on the checks, some ranging higher than others. This percentage was much below the expected, yet it served to indicate the value of the treatments.

In counting the percentage of smut on the treated plots every row was observed. In no instance did the formalin treated plots show any smut. This was contrary to expectations, expecially in the case of one to forty solution when applied in small amounts. Such results can hardly be accounted for since there was not a check that was not infected.

The plots treated with hydrogen peroxide showed as much smut as the check plots. It is no doubt safe to say that such peroxide treatments as were used can not be relied upon to control the oat smut.

It has been recognized for some time that climatic conditions have more or less influence on the intensity of the oat smut disease. When the seeding period is followed by warm weather a greater percentage of smut has been observed under similar conditions than when followed by cool weather. This is due in part to the maximum temperature of the smut spore being comparatively high. This, together with the adaptability of the oat plant to a cool moist climate, may account for the comparatively small percentage of smut in the test plots. The reverse conditions would result with wheat owing to the fact that wheat does best in a warm seed bed.

While some satisfactory results have been secured in regard to various formalin solutions and their methods of application it is desirable that the experiments be conducted one or more seasons under more favorable conditions. However, it may be safe to conclude that solutions as strong as one pint of formalin to twenty gallons of water when applied at the rate of six pints per bushel and covered for a period of six to twelve hours will control the oat smut without materially decreasing the vitality of the seed.

BIBLIOGRAPHY.

1. *Arthur, J. C.*, The loose smut of oats: Indiana Station Bulletin 35, 1891.
2. *Arthur, J. C.*, Formalin for grain and potatoes: Indiana Station Bulletin 77, pp. 38-44.
3. *Beattie, R. K.*, The formalin treatment for oat smut: Washington Station Bulletin 54.
4. *Bedford, S. A.*, Copper sulphate as a smut preventive: Canada Exp't. Farm Rpt., 1893, pp. 237-238, Rpt. 1900.
5. *Bolley, H. L.*, On the relation of the time of seeding and the period of development to the development of rust and smut of oats: Proc. Soc. Promotion Agr. Sci., 1896, pp. 70-75.
6. *Bolley, H. L.*, Studies upon the smut of small grain: N. D. Station Bulletin 1, 1891; Bulletin 19, 1895; Bulletin 27, 1897; Bulletin 37, 1899; Bulletin 87, 1910.
7. *Bowman, M. L.*, Treatment of smut in oats, etc.: Iowa Station Bulletin 89.
8. *Burrus, M. F.*, Dissemination of diseases by means of the seed of the host plant: Proc. Ind. Acad. Sci., 1908, pp. 113-122.
9. *Brefeld, Oscar*, Untersuchungen aus dem Gesedmmtge biete der Mykologie: Heft 11, 1895.
10. *Brefeld, O.*, and *R. Falck*, Flower infection of smuts: Untersuch. Gesam. Geb. Mykol., 1905, No. 13; also in Bot. Centbl., 101, 1906, No. 8, pp. 212-213.
11. *Buchanan, J. A.*, Treatment of grain for smut: Rpt. Ontario Agr. College and Experiment Farm, 32, 1906, pp. 176-178.
12. *Clinton, C. P.*, Smuts of Illinois: Ills. Sta. Bul. 57, 1900.
13. *Close, C. P.*, Results of the oat smut in 1892: N. Y. Station Bulletin 131.
14. *Cook, M. T.*, Grain smuts—their causes and treatments: New Jersey Station Circular 36.
15. *Cory, V. L.*, Coöperative grain investigations at McPherson, Kansas, 1904-1909: U. S. Dept. Agr.; Bur. Plant Industry, Bulletin 240.
16. *Duggar, J. F.*, Smut in oats: Alabama Station Bulletin 95, 175-180.
17. *Flagg, C. O.*, Loose smut of oats: R. I. Station Bulletin 15, 1892.
18. *Foster, L.*, On the prevention of smuts: Montana Station Bul. 10; 40-46.

19. *Fox, C. P.*, Methods of preventing smut of wheat and oats: Idaho Station Bulletin 534.
20. *Freeman, E. M., and E. C. Stackman*, The smuts of grain crops: Minnesota Station Bulletin 122.
21. *Freeman, E. M.*, Minnesota plant diseases: Rpt. of the Survey, Botanical Series, Vol. 5, 1905, pp. 59, 156, 157, 221, 223.
22. *Güssow, H. T.*, Smut diseases of cultivated plants—their cause and control: Canada Cent. Exp't. Farm Bulletin 73.
23. *Georgeson, C. C.*, Oats treated with hot water to prevent smut: Kansas Station Bulletin 29, 1891.
24. *Georgeson, C. C., and others*, Change of soil and its relation to oat smut: Kansas Sta. Bulletin 63, 213-226.
25. *Goff, E. S.*, Prevention of oat smut: (a) Wisc. Sta. Rpt. 1893; 228-250; (b) Bul. 50, 1896; (c) Wisc. Sta. Rpt. 1909, pp. 363-367.
26. *Harwood, P. M., and P. G. Holden*, Hot water treatment of oats and wheat: Mich. Sta. Rpt. 1892, pp. 280-288.
27. *Henderson, L. F.*, Experiments with oat and wheat smut: Idaho Station Bulletin 53.
28. *Jackson, H. S.*, Diseases of field crops: Del. Station Bul. 83.
29. *Jensen, J. L.*, Propagation and prevention of smuts in oats and barley: Jour. Roy. Ag. Sc., S.S. 11, 1888.
30. *Jensen, J. L.*, Experiments with hot water for the prevention of smut in spring grains: Lc. Cir. E: S. R. Vol. 5, pp. 309-311.
31. *Jones, L. R.*, Brief notes on smut of oats: (a) Vt. Sta. Rpt. 1890, pp. 129-144; (b) Vt. Sta. Bulletin 32.
32. *Johnson, C. E.*, The smut of wheat and oats: U. S. Dept. Agr. Farmer's Bul. 507.
33. *Kellerman, W. A., and W. T. Swingle*, Enemies of the Smut disease: Kansas Station Report, 1889, pp. 213-288.
34. *Lutman, B. F.*, Life history and structure of certain smuts: Abs. in Science New Ser. XXXI, 1911, No. 802, pp. 747-8.
35. *Lawrence, W. H.*, Diseases of plants: Washington Station Bulletin 7, special Ser. pp. 75-102.
36. *Masse, George*, Diseases of cultivated plants and trees: Edinburgh, 1910 Edition, p. 339.
37. *Moore, R. A.*, Oat smut in Wisconsin: (a) Wisc. Sta. Bulletin No. 98, Bulletin 111; Wisc. Sta. Rpt., 1903, pp. 363-367.
38. *McCready, S. B., and C. A. Zavitz*, Test of various treatments for oat smut, vitality of spores, selection and hybridization as a means of control: Ontario Agr. Col. Rpt. 36, 1910.
39. *Pammel, L. H.*, Prevention of oat and corn smut: (a) Iowa Sta. Bulletin No. 20, 1893. (b) Iowa Geological Survey Bul. 1, pp. 238-243.
40. *Pammel, L. H.*, Experiments with fungicides: Iowa Station Bulletin 24, pp. 985-990.* Sec. Bul. I, Ia. Geological Survey.
41. *Mackey, Angus*, The use of formalin, bordeaux mixture and bluestone as smut preventatives: Canada Expt. Farm Rpts. 1898, p. 336.

42. *Mills, A. A.*, Treatment of oat smut: Utah St. Rpt., 1893, pp. 225, 228.

43. *Raum, T. K.*, The influence of the time of sowing on the occurrence of loose smut in oats: Tidsskv. Landbor. Plateavl., 7, 1901, pp. 142-148; Synop. Expt. St. Rpt., Vol. 14, p. 877.

44. *Raum, T. K.*, Treating oats with formalin: Prakt Bl. Pflanzenbau u. Schutz, N. Ser., 5, 1905, No. 11, p. 127-128; Synop. Expt. Sta. Rec. Vol. 19, p. 251.

45. *Saunders, W.*, Prevention of oat smut: Canada Expt. Farm Rpts., 1899.

46. *Scribner, F. Lamson*, Treatment of certain fungus diseases of plants: Tenn. Sta. Bul. "special C", 1890.

47. *Selby, Augustine D.*, Smut of oats and its prevention: Ohio Station Bulletin 64, 1895.

48. *Shaw, R. S.*, Formalin treatment for grain smut: Montana Station Bulletin 32.

49. *Shutt, Frank T.*, Analyses and action of formalin: Canada Expt. Farm Rpt., 1906, pp. 151, 153.

50. *Sorauer, P.*, Disease of plants: Handbook of plant diseases, Berlin, 1908, pp. 314-316.

51. *Stewart, R., and J. Stephens*, The effect of formalin on the vitality of seed grain: Utah Sta. Bulletin 108, pp. 145-156.

52. *Stevens, F. L.*, Prevention of oat and wheat smut: N. C. Station Rpt., 1908; also Bulletin No. 212.

53. *Stevens, F. L., and J. G. Hall*, Diseases of Economic Plants: 1910 Edition, pp. 319-323.

54. *Tillinghast, J. A.*, Treatment of seed oats to prevent smut: R. I. Station Rpt. 1898, pp. 192-203.

55. *Thomas, M. B.*, The effect of formalin on germinating oats: Proc. Ind. Acad. Sci., 1897, pp. 144, 148.

56. *Thomas, M. B.*, Some field tests with formalin: Proc. Ind. Acad. Sci., 1898, pp. 62-64.

57. *Tebeuf, Karl Freiheer von.* English Edition by Smith, Wm. G. Diseases of plants: 1897, pp. 284-288.

58. *Ward, H. Marshall*, Diseases in plants: 1901 edition, pp. 117, 143, 162, 190.

59. *Warburton, C. W.*, Oat smut: Field Crops, 1912, p. 202-203.

60. *Wheeler, W. A.*, Preliminary experiments with vapor treatments for the prevention of stinking smut of wheat: S. D. Sta. Bulletin 89, 1904.

61. *Wilcox, E. V.*, Smut in small grains: Montana Sta. Bul. 22, pp. 24-28.

62. *Wilcox, E. M.*, Smuts of Nebraska Cereals: Nebraska Station Bulletin 131.

63. *Willis, Clifford*, Treatments for oat smut: South Dakota Station Bulletin 110, 1908.

64. *Wolff, E.*, Der Brand des Getreides, Halle, Germany, 1874.

THE WHITE WATERLILY OF IOWA.

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Most of the known species of waterlily (*Nymphaea* Sm.) are extremely variable. The student feels obliged to recognize certain extreme forms as species. These are often restricted geographically. But where their habitats are connected by continuous land areas, the intermediate country is usually populated by a series of waterlilies which grade insensibly from one extreme to the other. The commoner white waterlilies of North America illustrate these conditions.

The basic species in the United States is *Nymphaea odorata* Ait. It is impossible sharply to demarcate Aiton's type form from the smaller and pinker variety, designated by Pursh as *Nymphaea odorata* var. *rosea* (commonly known as *N. odorata* var. *minor* Sims). In the Atlantic coastal plain the variety is the commoner form, from Nova Scotia to Delaware. At a few isolated stations the whole flower is pink, giving the *N. odorata rosea* of gardens. This plant may be designated as *N. odorata rosea* forma *rubra* (cf. Rev. Horticole 1881, p. 406). From Delaware to Florida the var. *gigantea* Tricker is the commoner plant. The typical *N. odorata* is found in the New England and Middle Atlantic states. The species ranges westward to Minnesota, Nebraska, Missouri and probably to Arkansas. Toward its western limits, however, it is much larger and coarser than in the east. And it seems to be this coarse form which runs on down into Mexico, and perhaps into Cuba and British Guiana.

In the region from Lake Champlain to Lake Michigan, *Nymphaea tuberosa* Paine is found. The species was first described from plants growing in central New York, and was so named on account of the many easily detached, tuber-like branches found on the rhizome. I have collected unmistakeable, though miniature, specimens at Trenton, New Jersey, where they were discovered by C. C. Abbott. This is the extreme southeastern limit of the species. A kindred form, probably a hybrid with

N. odorata, occurs in Lake Hopatcong, New Jersey. MacMillan states that *N. odorata* and *N. tuberosa* occur together in Minnesota. Fitzpatrick and Shimek report *N. tuberosa* from Iowa.

Unfortunately the separation of *N. odorata* and *N. tuberosa* is extremely difficult without fresh material and very complete specimens or notes. Indeed, it may yet be proven that none of the supposed distinctions are constant, and that the two species cannot be maintained. The following table shows what the differences are said to be.

NYMPHÆA ODORATA Ait.	NYMPHÆA TUBEROSA Paine.
Flowers—7-15 cm. across, open from 6 a. m. to 12 m., very sweet scented.	*Flowers*—10-23 cm. across, open from 8 a. m. to 1 (or 2-3) p. m., odorless.
Peduncle—purplish green, 0.3-0.5 cm. in diameter; coiled 5-9 turns in fruit.	*Peduncle*—green, 0.5-0.9 cm. in diameter; coiled 3 turns in fruit.
Sepals—often purplish outside.	*Sepals*—green.
Petals—23-32, ovate to elliptic-lanceolate.	*Petals*—obovate or almost spatulate.
Stamens—becoming linear or filamentous at center of flower.	*Filaments*—nearly all broader than anthers.
Seeds—0.23x0.16 cm.; aril one-fourth longer than seed.	*Seeds*—0.44x0.28 cm.; aril about as long as the seed, or shorter.
Leaves—usually more or less purplish beneath; angles of sinus not at all produced.	*Leaves*—pure green beneath, angles of sinus slightly produced.
Petioles—reddish green to dark purplish red, evenly colored.	*Petioles*—green, with longitudinal red-purple stripes.
Branches of rhizome—few, attached by a base 1.3-2 cm. in diameter.	*Branches of rhizome* (tubers)—very numerous, attached by a slender neck 0.3-0.8 cm. in diameter and very readily detaching.
Stipules?	*Stipules?*
Surface of pollen?	*Surface of pollen?*
Relative length of stamens and petals?	

Of all of these distinctions the most certain test is the presence or absence of tubers. Next best is the presence of stripes of red-purple on the petioles in *N. tuberosa*. I have never known this to fail in unquestionally authentic fresh material. In my limited experience, the time of opening of the flowers has been highly characteristic. The large seeds with relatively small arils are easily recognized in *N. tuberosa*. But critical study of much material is necessary to ascertain to what extent these features are constant and diagnostic.

In the Gray Herbarium of Harvard University and in the private collection of Mr. J. R. Churchill I have examined material of these species, variously labelled as *N. odorata*, *N. tuberosa* or *N. reniformis*, from Iowa (Wabonsie Slough, Fremont county, coll. Fitzpatrick, No. 4426), Wisconsin, Minnesota, Missouri and Illinois. Of all of these only one (coll. E. E. Sherff, Wolf Lake, Chicago, June 10, 1911) has the form of flower of *N. tuberosa*. But a note attached to the specimen declares that the flowers are fragrant!

It seems highly desirable, therefore, that critical studies should be made of the white waterlilies of all of the Great Lake region, and the Central states. Every detail mentioned in the table given above should be carefully examined into. Only thus can the taxonomic value and the range of these plants be determined. At present I do not place entire confidence in any of the published names. I would be glad to serve as a medium of exchange for observations on this subject.

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