TRANSACTIONS

OF

THE ACADEMY OF SCIENCE OF ST. LOUIS.

VOL. VIII.

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iii

CONTENTS.

MEMBERS.

1. PATRONS.

Harrison, Edwin........................3747 Westminster pl.

2. ACTIVE MEMBERS.

Adkins, James..........................3901 Park av.
Alden, John T..........................Colonial bldg.
Alt, Adolph ....3036 Locust st.

Bailey, Charles........................87 Vandeventer pl.
Bain, Robert E. M......................Century bldg.
Ball, David C..........................310 Merchants' Exch.
Barck, C...............................2715 Locust st.
Bartlett, George M.....................215 Pine st.
Baumgarten, G..........................2643 Chestnut st.
Becktold, Wm. B........................212 Pine st.
Bernays, A. C..........................3623 Laclede av.
Biebinger, F. W........................1421 S. 11th st.
Bixby, W. K............................13 Portland pl.
Bliss, M. A............................4929 Lotus av.
Boogher, John H........................4034 Delmar boul.
Bouton, Charles L......................2709 Park av.
Branch, Henry..........................4314 Washington av.
Bremer, Ludwig.........................3723 West Pine boul.
Brennan, Martin S......................1414 O'Fallon st.
Brookings, Robert S....................2329 Locust st.
Brown, Daniel S........................2212 DeKalb st.
Bryson, John P.........................209 N. Garrison av.
Budgett, S. P..........................3810 Washington av.
Burg, Wm...............................1756 Missouri av.
Burnett, E. C..........................University Club.
Burroughs, W. S........................240 Dickson st.
Busch, Adolphus ....Busch pl.

Cale, George W., Jr....................4403 Washington boul.
Carpenter, George O....................Russell and Compton avs.
Carter, Howard ....Planters' Hotel.

Chaplin, Winfield S....................3636 West Pine boul.
Chase, E. C..............................3325 Morgan st.
Chauvenet, Louis..................... 5501 Chamberlain av.
Chouteau, Charles P..................918 Security bldg.
Clifford, Alfred ....4168 West Pine boul.
Close, James A..........................2031 Olive st.
Collins, Robert E.......... .. ..3811 Westminster pl.
Compton, P. C...........................4156 Washington boul.
Comstock, T. G.........................3401 Washington av.
Coulter, John M ....University of Chicago, Chicago, Ill.
Crandall, Geo. C.......................620 N. Garrison av.
Crunden, Frederick M ....Public Library.
Curtis, Wm. S...........................St. Louis Law School.
Cushman, Allerton S..................Harvard University, Cambridge, Mass.

Dameron, E. C..........................Clarksville, Mo.
Davis, H. N...............................56 Vandeventer pl.
Davis, John D............................421 Olive st.
Diehm, Ferdinand......................1835 Kennett pl.
Dodd, S. M................................415 Locust st.
Douglas, A. W...........................9th and Spruce sts.
Drake, George S ....Boatmen's Bank.
Duenckel, F. W.........................1936 Louisiana av.
Durant, George F......................9 Benton pl.

Eggert, Henry........... ....1001 Collinsville av., East St. Louis, Ill.
Eberlein, W. P..........................3655 Cleveland av.
Eliot, E. C.................................5468 Maple av.
Eliot, Henry W.................. .... 2635 Locust st.
Engler, Edmund A.....................Washington University.
Erker, A. P................................617 Olive st.
Espenschied, Charles ....3500 Washington av.
Euston, Alexander.....................3730 Lindell boul.
Evers, Edward...........................1861 N. Market st.
Ewing, A. E............. ....3333 Washington av.

Ferriss, Franklin............. ....5828 Cabanne av.
Fischel, W. E..... ....2647 Washington av.
Flersheim, George W.................1008 Locust st.
Forbes, S. A...............................Urbana, Ill.

Fordyce, John R. ....3634 Washington boul.
Francis, D. R. ....4421 Maryland av.
Frankenfield, H. C. ....U. S. Weather Bureau, Washington, D. C.
Frerichs, Frederick W. ....Herf & Frerichs Chem. Co.
Fruth, Otto J. ....3066 Hawthorne boul.
Fry, Frank R. ....3133 Pine st.
Funkhouser, R. M. ....3534 Olive st.

Gazzam, J. B. ....514 Security bldg.
Glasgow, Frank A. ....2608 Locust st.
Glasgow, William C. ....2847 Washington av.
Goodman, C. H. ....3329 Washington av.
Gottschalk, Fred. F. ....619 Pine st.
Graham, B. B. ....3500 Morgan st.
Graves, W. W. ....1943 N. 11th st.
Gray, M. L. ....604 Houser bldg.
Green, John ....2670 Washington av.
Gregory, E. H., Jr. ....3525 Lucas av.
Grindon, Joseph ....509 N. Theresa av.
Grocott, Willis H. ....1812 Coleman st.
Gurney, James ....Tower Grove and Magnolia avs.

Haarstick, Henry C. ....Main and Walnut sts.
Hambach, G. ....Washington University.
Hammon, W. H ....U. S. Weather Bureau, San Francisco, Cal.
Hardaway, W. A. ....2922 Locust st.
Hartmann, R. ....14 S. 2d st.
Herthel, Adolph ....1739 Waverly pl.
Herzog, William ....2321 Whittemore pl.
Hirschberg, F. D ....3818 Lindell boul.
Hitchcock, A. S. ....Manhattan, Kas.
Hitchcock, Henry ....709 Wainwright bldg.
Hodgman, Charles ....300 N. 14th st.
Holman, M. L. ....3744 Finney av.
Holmes, J. M. ....3810 Page av.
Hough, Warwick ....3877 Washington boul.
Hugunin, F. U. ....915 Olive st.
Hunicke, H. A ....3532 Victor st.
Hurter, Julius ....2346 S. 10th st.

Ives, Halsey C. ....Museum of Fine Arts.

James, John A. James..............2836 Lafayette av.
Jester, E. T..........................c/o Liggett & Myers Co.
Jewett, Eliot C.......................Monterey, Mex.
Johnson, Dr. J. B.....................4244 Washington boul.
Johnson, Professor J. B............Washington University.
Johnson, R. DeO.....................Flat River, Mo.
Jones, Breckinridge ....4th and Pine sts.
Judson, Frederick N.................421 Olive st.

Kennett, A. Q..........................2916 Lucas av.
Keyes, Charles R......................944 Fifth st., Des Moines, Ia.
Kinealy, J. H...........................Washington University.
King, Goodman.......................78 Vandeventer pl.
Kinner, Hugo...........................1103 Rutger st.
Kinsley, Carl ....Washington University.
Kinsman, G. C..........................Decatur, Ill.
Kline, George R.......................215 Pine st.
Kodis, Theo.............................3450 Sidney st.
Kolbenheyer, F ....2006 Lafayette av.
Krall, George W.......................Manual Training School.
Kribben, B. D..........................701 Bank of Commerce bldg.
Kromrey, Hugo........................513 Walnut st.

Lackland, R. J.........................1623 Locust st.
Langsdorf, A. S.......................3133 Laclede av.
Lazell, E. W.............................Spencer, Mass.
Leighton, George B.................803 N. Garrison av.
Leighton, George E.................803 N. Garrison av.
Lemoine, E. S..........................1622 Washington av.
Letterman, George W...............Allenton, Mo.
Lichter, John J., Jr..................5305 Virginia av.
Loeb, H. W ....3536 Olive st.
Lumelius, J. Geo...... ....1225 St. Ange av.

Mack, Charles J ....113 N. Broadway.
Madill, George A ....4140 Lindell boul.
Mallinckrodt, Edward...............26 Vandeventer pl.
Markham, George D.................Colonial bldg.
Matthews, Leonard...................300 N. 4th st.
McElwee, L. C.........................215 S. Jefferson av.
McMillan, Wm.........................25 Portland pl.
Meier, Frederick................ .....2340 Whittemore pl.
Meier, Theo. G........................421 Olive st.

Merrell, Albert..........................3814 Washington boul.
Miller, Charles F.......................1751 Missouri av.
Moore, Robert...........................61 Vandeventer pl.
Morton, I. W............................9th and Spruce st.
Mudd, Harvey G.........................2604 Locust st.
Mudd, Henry H..........................2604 Locust st.
Muegge, Aug. H.........................2712 Franklin av.

Nagel, Charles..........................2044 Lafayette av.
Nelson, N. O............................8th and St. Charles sts.
Neville, J. E...........................3960 Delmar boul.
Nipher, Francis E.......................Washington University.
Norton, J. B. S.........................Mo. Botanical Garden.

Olshausen, E. P.........................1115 Rutger st.
Olshausen, George R.....................13 Artillerie st., Berlin, Germany.
O'Reilly, A. J..........................33 City Hall.
O'Reilly, Robert J......................3411 Pine st.
Overstolz, Herman.......................100 N. Broadway.

Pammel, L. H............................Ames, Ia.
Parker, Geo. W..........................417 Pine st.
Parsons, Charles........................2804 Pine st.
Pegram, George H........................195 Broadway, New York City.
Pettus, W. H. H.........................2834 Chestnut st.
Pickard, John...........................Columbia, Mo.
Pike, S. B..............................Amer. Central bldg.
Pitzman, Julius.........................1900 S. Compton av.
Post, M. Hayward........................3015 Lucas av.
Potter, William B.......................3312 Washington av.
Preetorius, Emil........................c/o Westliche Post.
Prewitt, T. F...........................3101 Pine st.
Primm, Alexander T......................c/o J. Kennard & Sons.
Pritchett, Henry S......................Supt. U. S. Coast Survey,
Washington, D. C.
Pulsifer, William H.....................Newton Centre, Mass.

Quaintance, A. L........................Lake City, Florida.

Ramel, A................................Washington University.
Ravold, Amand...........................2806 Morgan st.
Robert, E. S............................Union Trust bldg.
Robertson, Charles......................Carlinville, Ill.

Roever, William H.................. 3628 St. Louis av.
Rolfs, P. H ....Lake City, Fla.
Runge, Edward C ....Supt. Insane Asylum.
Russell, Colton.........................4652 Wagoner pl.

Sander, Enno...........................129 S. 11th st.
Sanger, Charles R......................Washington University.
Schmalz, Leopold. ....2824 Shenandoah av.
Schneck, Jacob..........................Mt. Carmel, Ill.
Schwarz, Henry.........................1723 Chouteau av.
Schweitzer, P...........................Columbia, Mo.
Scott, Henry C.........................64 Vandeventer pl.
Seddon, James A.......................1515 Locust st.
See, T. J. J...............................Montgomery City, Mo.
Seever, William J......................1600 Locust st.
Senseney, E M.. ....2829 Washington av.
Sheldon, W. L.................. ......4200 Morgan st.
Shepley, John F........................60 Vandeventer pl.
Simmons, E. C..........................9th and Spruce sts.
Simmons, W. D....................... Simmons Hardware Co.
Sluder, Greenfield,............... .....2647 Washington av.
Smith, D. S. H.........................3646 Washington boul.
Smith, Holmes..........................Washington University.
Smith, Irwin Z.................. ......87 Vandeventer pl.
Smith, Jared G.........................Dept. Agriculture,
Washington, D. C.
Spencer, H. N...........................2725 Washington av.
Spiegelhalter, Joseph..................2166 Lafayette av.
Starr, John E............................West and Horatio sts., N. Y. City.
Staudinger, B...........................1703 Olive st.
Stedman, J. M ....Columbia, Mo.
Stevens, Charles D.....................1749 S. Grand av.
Stone, Chas. H..........................Harbor Commr., City Hall.
Straub, A. W.............................1553 S. Grand av.
Strauss, Julius C........................3516 Franklin av.
Sutter, Otto...............................City Hospital.

Taussig, Albert E.......................2647 Washington av.
Taussig, William.......................3447 Lafayette av.
Teichmann, William C................1141 Market st.
Terry, Robert J.........................Mo. Medical College.
Thacher, Arthur........................4109 Washington boul.
Thomas, John R........................4th and Vine sts.

Timmerman, A. H..................Rolla, Mo.
Tittmann, Eugene C.................1811 Kennett pl.
Tittmann, Harold H..................3726 Washington boul.
Trelease, William.....................Mo. Botanical Garden.
Turner, John W.......................717 N. Garrison av.
Tyrrell, Warren A....................c/o St. L., P. & M. Ry. Co.,
Springfield, Ill.

Updegraff, Milton.................. Columbia, Mo.

Vallé, Jules F..........................3303 Washington av.
Vanlandingham, A. J ....500 Chamber of Commerce.
Vickroy, W. R.........................3029 Washington av.
Von Schrader, George F..............Wainwright bldg.
Von Schrader, Otto U.................3749 Westminster pl.
Von Schrenk, Hermann...............1724 Washington av.

Wall, L. J. W..........................21st and Morgan sts.
Walsh, Edward, Jr.....................Miss. Glass Co.
Watts, M. F.............................4362 Morgan st.
Wheeler, H. A..........................3124 Locust st.
Whelpley, Milton H...................2342 Albion pl.
Whitaker, Edwards....................300 N. 4th st.
Whitten, J. C...........................Columbia, Mo.
Whittier, Charles T...................2727 Olive st.
Winkelmeyer, Christopher...........3540 Chestnut st.
Winslow, Arthur.......................Lyceum bldg., Kansas City, Mo.
Wislizenus, Fred......................1817 Longfellow av.
Witt, Thomas D........................6th and Olive sts.
Wittenberg, Paul.......................2d and Pine sts.
Wood, O. M.............................3016 Caroline st.
Woodward, C. M......................3013 Hawthorne boul.

Yeatman, James E.....................1410 E. Grand av.

THE ACADEMY OF SCIENCE OF ST. LOUIS.

ORGANIZATION.

The Academy of Science of St. Louis was organized on the 10th of March, 1856, in the hall of the Board of Public Schools. Dr. George Engelmann was the first president.

CHARTER.

On the 17th of January following, a charter incorporating the Academy was signed and approved, and this was accepted by vote of the Academy on the 9th of February, 1857.

OBJECTS.

The act of incorporation declares the object of the Academy to be the advancement of science and the establishment in St. Louis of a museum and library for the illustration and study of its various branches, and provides that the members shall acquire no individual property in the real estate, cabinets, library, or other of its effects, their interest being usufructuary merely.

The Constitution, as adopted at the organization meeting and amended at various times subsequently, provides for holding meetings for the consideration and discussion of scientific subjects; taking measures to procure original papers upon such subjects; the publication of transactions; the establishment and maintenance of a cabinet of objects illustrative of the several departments of science, and a library of works relating to the same; and the establishment of relations with other scientific institutions. To encourage and promote special investigation in any branch of science, the formation of special sections under the charter is provided for.

MEMBERSHIP.

Members are classified as active members, corresponding members, honorary members, and patrons. Active membership is limited to persons interested in science, though they need not of necessity be engaged in scientific work, and they alone conduct the affairs of the Academy, under its Constitution. Persons not living in the city or county of St. Louis, who are disposed to further the objects of the Academy by original researches, contributions of specimens, or otherwise, are eligible as corresponding members. Persons not living in the city or county of St. Louis are eligible as honorary members by virtue of their attainments in science. Any person conveying to the Academy the sum of one thousand dollars or its equivalent becomes eligible as a patron.

Under the By-Laws, resident active members pay an initiation fee of five dollars and annual dues of six dollars. Non-resident active members pay the same initiation fee, but annual dues of three dollars only. Patrons, and honorary and corresponding members, are exempt from the payment of dues. Patrons and all active members not in arrears are entitled to one copy of each publication of the Academy issued after their election.

Since the organization of the Academy, 824 persons have been elected to membership, of whom, at the present time, 251 are carried on the active list. One person, Mr. Edwin Harrison, has been elected a patron. The present list of corresponding members includes 204 names.

OFFICERS AND MANAGEMENT.

The officers, who are chosen from the active members, consist of a President, two Vice-Presidents, Recording and Corresponding Secretaries, Treasurer, Librarian, three Curators, and two Directors. The general business management of the Academy is vested in a Council composed of the President, the two Vice-Presidents, the Recording Secretary, the Treasurer and the two Directors.

The office of President has been filled by the following well-known citizens of St. Louis, nearly all of whom have been eminent in some line of scientific work: George Engelmann, Benjamin F. Shumard, Adolphus Wislizenus, Hiram A. Prout, Dr. John B. Johnson, James B. Eads, William T.

Harris, Charles V. Riley, Francis E. Nipher, Henry S. Pritchett, John Green, Melvin L. Gray, and Edmund A. Engler.

MEETINGS.

The regular meetings of the Academy are held at its rooms, 1600 Locust Street, at 8 o'clock, on the first and third Monday evenings of each month, a recess being taken from the second June meeting to the first October meeting, inclusive. These meetings, to which interested persons are always welcome, are devoted in part to the reading of technical papers designed for publication in the Academy's Transactions, and in part to the presentation of more popular abstracts of recent investigation or progress. From time to time, public lectures calculated to interest a larger audience are provided for in some suitable hall.

LIBRARY.

After its organization, the Academy met in Pope's Medical College, where a creditable beginning had been made toward the formation of a museum and library, until May, 1869, when the building and museum were destroyed by fire, the library being saved. The library now contains some 12,900 books and 9,000 pamphlets, and is open during certain hours of the day for consultation by members and persons engaged in scientific work.

PUBLICATIONS AND EXCHANGES.

Eight octavo volumes of Transactions, averaging 665 pages, have been published since the organization of the Academy, and widely distributed. Two quarto publications have also been issued, one from the Archaeological section, being a contribution to the archaeology of Missouri, and the other a report of the observations made by the Washington University Eclipse Party of 1889. The Academy now stands in exchange relations with 527 institutions or organizations of aims similar to its own.

MUSEUM.

Since the loss of its first museum, in 1869, the Academy has lacked adequate room for the arrangement of a public museum, and, although small museum accessions have been received and cared for, its main effort of necessity has been concentrated on the holding of meetings, the formation of a library, the publication of worthy scientific matter, and the maintenance of relations with other scientific bodies, through its active membership, which includes many business and professional men who are interested in the work and objects of the Academy, although not themselves investigators.

December 31, 1898.

RECORD

From January 1, 1898, to December 31, 1898.

January 3, 1898.

President Gray in the chair, nineteen persons present.

The President presented a report on the condition of the Academy for the year 1897.*

The Treasurer submitted his annual report, showing invested funds to the amount of $6,000.00, and a balance carried forward to the year 1898 of $603.41.†

The Librarian submitted his annual report.‡

The nominating committee reported that 95 ballots had been counted, and the following officers for 1898 were declared elected: —

President	Edmund A. Engler.
First Vice-President	Robert Moore.
Second Vice-President	D. S. H. Smith.
Recording Secretary	William Trelease.
Corresponding Secretary	Joseph Grindon.
Treasurer	Enno Sander.
Librarian	Gustav Hambach.
Curators	Gustav Hambach, Julius Hurter.
Directors	M. H. Post, Amand Ravold.

It was announced, as a result of the letter ballot, that Article IV. of the Constitution had been amended so as to read "Three Curators" instead of "Board of Curators."

President-elect Engler, being called to the chair, briefly

* Transactions 7: lxxvii. † Transactions 7: lxxviii. ‡ Transactions 7: lxxix.

addressed the Academy, and in the course of his remarks called attention to the long and faithful service of Mr. M. L. Gray, the retiring President. On motion, a committee, composed of Professor Nipher, Mr. Trelease and Dr. Sander, was appointed to prepare a resolution expressive of the Academy's appreciation of Mr. Gray's services.

Dr. Amand Ravold spoke informally of formaldehyde gas as a disinfectant, and exhibited several forms of apparatus adapted to its use. It was stated that although, in confined spaces, the gas has proved to be an effective disinfectant, which has the merit of not injuring the most delicate fabrics or polished metal surfaces, its germicide action in dwelling rooms has thus far proved less satisfactory than that of sulphur dioxide and chlorine, so far as it has been tested by the Health Department of the City of St. Louis, so that, as yet, the Health Department has not found it possible to employ it as a substitute for the older and in some respects more objectionable disinfectants.

Two persons were proposed for active membership.

January 17, 1898.

President Engler in the chair.

The committee appointed at the last meeting to take suitable action on the withdrawal of Mr. M. L. Gray from active participation in the affairs of the Academy submitted the following report: —

To the President and Members of the St. Louis Academy of Science:

Gentlemen: Your committee, appointed to recommend suitable action on the withdrawal of Mr. M. L. Gray from service in your council, beg leave to report as follows: —

The committee does not feel that we are in any sense taking leave of our associate and friend, but we feel that his long and devoted service to the Academy has entitled him to ask our consideration in seeking relief from the drudgery and responsibilities of business and executive details. Surely it was not the desire to do work of this kind that has caused him for so many years to be so constantly in attendance upon our meetings.

We know that his request to be relieved of such duties is not due to any decrease in his interest in the cause which the Academy represents. We know that his zeal in promoting the higher interests of the Academy will still continue. But it is proper and fitting that we should at this time assure him of our grateful appreciation of his long and faithful services to the Academy. And we hope that we shall continue for many years to enjoy his genial presence among us.

A paper by Mr. Charles Robertson, entitled New or little known North American Bees, was read in abstract.

Prof. A. C. Bernays addressed the Academy on biological facts as evidence of man's place in nature. He illustrated certain facts from the ontogeny of man by description and blackboard sketches, and tried to explain the anatomical peculiarities in the structure of man and the lower animals by the biogenetic law of Haeckel. He also made some suggestions about the best method of studying and of teaching anatomy. It was claimed that in the biogenetic law of Haeckel a scientific background, or rather a working hypothesis, was given, by means of which the recorded facts of zoology, botany, paleontology, etc., were made understandable and really became useful to science. He also gave a definition and illustration of the meaning of the term differentiation as used in biology.

Mr. George W. Parker, Dr. Otto Sutter and Mr. O. M. Wood, of St. Louis, were elected to active membership.

Twenty-four persons were proposed for active membership.

FEBRUARY 7, 1898.

President Engler in the chair, fourteen persons present.

Mr. J. B. S. Norton read a paper by Professor A. S. Hitchcock, on the ecological plant geography of Kansas.

Professor L. H. Pammel spoke informally on the anatomical characters of seeds from the standpoint of systematic botany.

The following persons were elected active members: James Adkins, Robert E. M. Bain, W. K. Bixby, Dr. James A. Close, Dr. Geo. C. Crandall, Wm. S. Curtis, George W. Flersheim, D. R. Francis, Dr. R. M. Funkhouser, Fred. F. Gottschalk, F. U. Hugunin, Breckinridge Jones, Frederick N. Judson, George R. Kline, John J. Lichter, Jr., Dr. H. W. Loeb, Wm. McMillan, Dr. Harvey G. Mudd, J. B. S. Norton, Warren A. Tyrrell, Dr. Jules F. Vallé, A. J. Vanlandingham, Dr. Henry Milton Whelpley, of St. Louis; Henry Eggert, of East St. Louis, Illinois.

Sixteen persons were proposed for active membership.

February 21, 1898.

President Engler in the chair, thirteen persons present.

Dr. R. J. Terry exhibited a specimen of a cervical rib from a human subject, and discussed the occurrence of structural anomalies of this character.

The following persons, resident in St. Louis, were elected active members: Wm. B. Becktold, Henry Branch, Wm. Burg, John D. Davis, Otto J. Fruth, J. B. Gazzam, Dr. W. W. Graves, Willis H. Grocott, A. Q. Kennett, Leonard Matthews, Theo. G. Meier, Dr. Albert Merrell, Aug. H. Muegge, Alexander T. Primm, John R. Thomas.

Seven persons were proposed for active membership.

March 7, 1898.

President Engler in the chair, twenty-eight persons present.

Professor C. M. Woodward presented a paper embodying an analytical discussion of the efficiency of gearing under friction, spur wheels with epicycloidal and involute teeth being considered.

Dr. Amand Ravold demonstrated the method, recently introduced by Philip Hanson Hiss, of differentiating the typhoid bacillus from *Bacillus coli-communis*, by the use of semi-solid acidulated media, in which, at blood temperature, the round colonies of the typhoid bacillus assume a peculiar fimbriated form of growth, because of the motility of the bacteria in the slightly yielding medium, which in most cases readily distinguishes them from the more whetstone-shaped colonies of the colon bacillus, which does not produce the peculiar fimbriation in plate cultures. In tube cultures in the same general medium, but prepared with a slighter acidity and somewhat less solidity, a uniform clouding of the entire tube, due to the swarming of the bacteria, was shown to be characteristic of the typhoid bacillus, while the colon bacillus was definitely confined to the immediate vicinity of the thrust. The media in both cases are made up without peptone. The formulae are: —

For plate cultures:		For tube cultures:	
Agar	10 grams.	Agar	5 grams.
Gelatine	25 "	Gelatine	80 "
Beef extract	5 "	Beef extract	5 "
Glucose	10 "	Glucose	10 "
Salt	5 "	Salt	5 "
Normal acid	20 cc.	Normal acid	15 cc.
The whole increased to 1000 cc.		The whole increased to 1000 cc.	

The growth of the two species in question, on potato and in milk cultures with litmus, was also demonstrated.

The following persons, resident in St. Louis, were elected active members: David C. Ball, Dr. E. C. Burnett, Ferdinand Diehm, Franklin Ferriss, Dr. L. C. McElwee, Chas. H. Stone, W. S. Vickroy, L. J. W. Wall.

Four persons were proposed for active membership.

March 21, 1898.

President Engler in the chair, fifteen persons present.

Professor J. B. Johnson spoke informally on some aspects of the manufacture and testing of Portland cement, reviewing the historical development of the cement industry from the time of Smeaton, and showing that the first true Portland cement had been made and patented in Yorkshire, England, in 1825, though it was not until about 1850 that it was known in London; and that its manufacture in Germany began at Stettin, in 1853, while it was not until 1875 that it was made in the United States. The statement was made that the increase in the use of this material now outruns the rapidly increasing production. The various methods of manufacture were outlined, and the theory was explained on which the various processes are based. The accepted theory of the hardening ingredients was given, and some of the standard methods of testing were described. Two improvements that the speaker hoped to see introduced in the standard methods of testing were considered in detail, — one, a modification of the form of the tension briquette, in which the stress should be more uniformly distributed; and the other, a mixing of two fairly uniform sizes of sand, one of which should just about fill the interstices of the other, so as to develop the benefits of fine grinding of the cement, which, it was explained, were lost when large gaps remained between the particles of sand, to be filled by the cement.

April 4, 1898.

No quorum present.

April 18, 1898.

President Engler in the chair, eighteen persons present.

Mr. Carl Kinsley read a paper on Series Dynamo Electric Machines.

Professor J. H. Kinealy made some informal remarks on the ventilation of schools, and by means of stereopticon views showed the different methods adopted for supplying the air required for ventilation to the different rooms of school houses.

The following persons, resident in St. Louis, were elected active members: W. P. Eberlein, Alexander Euston, Harold H. Tittman, George F. von Schrader.

One person was proposed for active membership.

May 2, 1898.

President Engler in the chair, sixteen persons present.

Mr. M. L. Holman, Water Commissioner of St. Louis, made an informal address on Present Methods in Water Filtration. He described the municipal systems of water filtration used at Hamburg, Berlin and other German cities which he had visited, and spoke of the problems to be solved in designing a filter plant for St. Louis. He spoke of the different methods of coagulating and getting rid of mud and sediment in water, and said he thought it was probable that a combination coagulating and filtering system would have to be used to purify the water for St. Louis.

Mr. Julius Pitzman, of St. Louis, was elected an active member.

May 16, 1898.

President Engler in the chair, thirteen persons present.

Mr. J. A. Seddon delivered an informal address on Floods in the Mississippi System. He discussed the floods of the Missouri and upper Mississippi rivers with regard to their relations to one another and to the floods of the lower Mississippi. He spoke of the great damage done by the floods to plantations and towns on the banks of the lower Mississippi, and of the means to be adopted for controlling the floods and preventing, as far as possible, this damage. His remarks were illustrated by maps and diagrams showing the flooded regions and the various quantities of water discharged by the rivers at different stages.

One person was proposed for active membership.

June 6, 1898.

President Engler in the chair, nineteen persons present.

Dr. Amand Ravold read a paper on Consumption from an Economic and Humanitarian Standpoint. He quoted statistics showing the yearly loss of life by consumption in St. Louis, and stated that on account of disabilities and deaths by consumption the loss to the city was not less than one and one-half million dollars yearly. He said that he did not believe in the isolation of consumptives, as the communication of the disease to well persons could be prevented by the exercise of simple sanitary precautions. He condemned the habit of spitting as unnecessary, dirty, and detrimental to the health of the community.

Dr. Howard Carter made a few remarks in regard to the occurrence of tuberculi in milk, and the danger of using milk from unhealthy cows.

Mr. Carl Kinsley showed the different methods of determining the frequency of an alternating current, and demonstrated that the frequency could be determined by the vibration of an air column, in a brass or glass tube, set in motion by the current.

Mr. W. C. G. Kirchner presented a paper entitled Contributions to the Fossil Flora of Florissant, Colorado.

Mr. M. L. Holman, of St. Louis, was elected an active member.

One person was proposed for active membership.

October 17, 1898.

President Engler in the chair, ten persons persent.

Mr. C. H. Thompson spoke of some interesting stylar movements of certain Marantaceae, connected with their pollination, his observations referring to *Maranta*, *Calathea* and *Thalia*.

Seven persons were proposed for active membership.

November 7, 1898.

President Engler in the chair, fourteen persons present.

Mr. James A. Seddon read a paper on Resistance to Flow in Hydraulics, in which the point was made that relatively a small part of this resistance, so far as open streams were concerned, was directly attributable to friction against the bottom and limiting banks, but that the resistance was found acting between accelerations and impacts, and showed in forced distortions of the free surface, from which forms the energy passed into internal motion.

The following persons were elected active members: William Herzog, Dr. Theodore Kodis, A. S. Langsdorf, J. George Lumelius, Herman Overstolz, of St. Louis; A. L. Quaintance, of Lake City, Florida; Dr. T. J. J. See, of Montgomery City, Missouri.

Two persons were proposed for active membership.

NOVEMBER 21, 1898.

President Engler in the chair, eleven persons present.

Dr. G. Hambach presented an oral abstract of a paper entitled A Revision of the Morphology of the Blastoideae, illustrating his remarks with numerous specimens and photographs.

The following persons, resident in St. Louis, were elected active members: Dr. Howard Carter, William H. Roever.

DECEMBER 5, 1898.

President Engler in the chair, twenty-six persons present.

Mr. H. von Schrenk presented by title a paper On the Mode of Dissemination of *Usnea barbata*.

Professor L. H. Pammel presented by title a paper on the Histology of the Caryopsis and Endosperm of some Grasses.

Dr. Theodore Kodis stated the results of some experiments on overcooling animal and vegetable tissues, in which it was shown that, as water may, under favorable conditions, be cooled to some distance below zero, centigrade, without freezing, — the temperature immediately rising to the freezing point the moment that freezing begins, and remaining there until the water is entirely solidified, then beginning once more to drop, — so, when animal and vegetable tissues are experimented on, they may be cooled to a temperature decidedly lower than the freezing point, under favorable conditions, before freezing begins, but that, when it begins, the temperature at once rises to the freezing point (which is always somewhat lower than that of pure water), remaining there until the process of freezing is complete, when it once more begins to fall. The speaker gave a short account of the current theories as to the mechanical constitution of protoplasm, and discussed the bearing on them of the phenomena when the solidification of overcooled tissues began.

Professors Nipher, Budgett and Green were elected a committee for the nomination of officers for the year 1899.

December 19, 1898.

President Engler in the chair, sixteen persons present.

The nominating committee reported the following nominations for officers for the year 1899 : —

President	Edmund A. Engler.
First Vice-President	Robert Moore.
Second Vice-President	D. S. H. Smith.
Recording Secretary	William Trelease.
Corresponding Secretary	Joseph Grindon.
Treasurer	Enno Sander.
Librarian	G. Hambach.
Curators	G. Hambach, Julius Hurter, Hermann von Schrenk.
Directors	M. H. Post, Amand Ravold.

Mr. O. M. Wood addressed the Academy on the Sociology of the Negro, emphasizing the negro's faithfulness, cheerfulness, and love of music; and in speaking of the prospects of the negro race for the future he laid stress on the fact that the negro is ever grateful for assistance from the white man, and fully realizes that his advancement is impossible without such assistance. The speaker's remarks were illustrated by lantern slides showing typical negroes in the savage state.

Reports of Officers for the Year 1898.

Submitted January 9, 1899.

The President addressed the Academy as follows: —

Gentlemen:

It devolves upon me, according to the time-honored custom of Presidents of this Academy, to make some remarks upon the present status o our society and the prospects for the future. I am glad to be able to congratulate the Academy upon its present condition. This Academy has never been without a nucleus of earnest workers in science, who form the life of the society, whose devotion to science enables us, in our modest way, to carry on our meetings in a truly scientific spirit, to devote our thoughts and attention, for at least two nights every month, to subjects which are aside entirely from the thoughts which actuate the greater part of our community. We are not led astray, and never have been led astray, by the spirit of commercialism which rules not only in our city but throughout our country; and I can safely say that we have kept the flame of pure science burning, though we have not been able to spread its light as broadly as we should like.

Yet it is a satisfaction to know that we do not lack for the devotion which has always characterized the members of this society, and in which the hope of the future lies. I am glad to be able to report, as you can see in detail from the reports of the other officers, a very satisfactory progress in a number of different directions.

In the membership I can report that during the past year we have added a net increase of 49, making at present a total active membership of 251. While the larger part of this membership consists of persons who do not attend our meetings, yet we are assured of their sympathy and encouragement, if by no other thing, by the mere fact that they are willing to contribute their annual dues for the sake of enabling the few who do the work to carry on the society and to print its publications. But in retaining and striving to increase this class of members, the Academy assumes a reciprocal obligation, and it is no doubt desirable that at least some of the meetings of the Academy should be devoted to the consideration of the growth of scientific knowledge, not necessarily such growth as has been brought about by the members of our own Academy, but the world's progress in science. To do this implies that we should have, at least occasionally, a statement of results in scientific work, in a form not too technical, in order that we may appeal to the larger part of the membership that we now have, retain their interest, and also increase the membership. The Council of the Academy has had such general lectures upon scientific progress in mind, and has made some effort to provide such popular evenings. It is a matter, however, of no little difficulty to find the man and the subject which will appeal to this larger class of members. Still, it is a thing which should be kept in mind, and I have no doubt that, as occasion offers, such discourses will be provided.

With reference to the meetings of the Academy, I may again congratulate the society. We have held fifteen regular meetings during the year, and the average attendance has been sixteen. While this is a comparatively small number, I think it will compare favorably with that of similar meetings of very much larger bodies in other cities, so that we have nothing to be ashamed of. At the same time, I think it is desirable, and I think it entirely feasible, by the means that I have indicated and by others, to increase the attendance.

We have made progress, also, with reference to the library. During the year we have increased the number of exchanges which are now receiving our Transactions, and from which we receive periodical publications, quite considerably. The total number of exchanges, as I am informed by the librarian, is now 527, scattered through various parts of the world; and from these societies we have received, during the year, very nearly a thousand numbers, — about 890, I think it is, of volumes, and 551 pamphlets, which, as you see, make a very considerable addition to our already extensive library.

Besides the actual increase in the contents of the library, arrangements have been made by the Council to increase the usefulness of the library, and I speak of this with considerable satisfaction, because I feel sure that the library is now more accessible and can be more easily used by scientific workers than ever heretofore. I refer particularly to the fact that the library room is now suitably heated, lighted, and furnished with tables on which any student may place the books taken from the shelves and use them. The library is always open, not only to every member of the Academy, but to any person, not a member of the Academy, who satisfies the officers that he is really a student in science and wishes to use and not abuse the books.

We have also made some progress with reference to our museum. As you are aware, one of the purposes of the Academy has been, from the very start, and still is, to provide a suitable museum. Progress in that direction has been very slow. The reason is very evident, namely, lack of money; and I doubt very much whether we shall ever be able to make much progress in that line until funds have been secured to enable us to build a permanent museum building, in which may be displayed the collections which we have and which we may acquire. But it would not only be futile, but I doubt whether it would be wise, to attempt to accumulate large collections, or collections of any considerable value, before we have a safe place in which to keep them. This of itself is a sufficient reason for effort in the direction of securing a permanent home for the Academy. This is one of the things that we have always had before us, and it is one which perhaps requires as much effort as anything which the Academy has before it. But notwithstanding the difficulties, we have begun the exhibition of at least one collection: I refer to the collection of meteorites, in which there are, I believe, twenty-five specimens, the value of which, as estimated by our librarian, is somewhere between $750 and $1,000. This value, of course, is somewhat fictitious, because we do not expect to offer them for sale. These specimens are now displayed in a suitable case, and the case stands on the second floor of this building. Space for exhibiting it has been kindly given us by the Historical Society.

We have made progress, also, with reference to our own publications. I think I am safe in saying that the publications of this Academy stand, from a scientific point of view, upon the level of those of any scientific society in the world, not only as to the quality of the material which we publish, — and I congratulate the Academy on the fact that great care has always been exercised in publication,— but also as to the amount in which the Transactions have been issued. To be definite in the statement, I will announce that we are just completing Volume VIII. of our Transactions, which consists of eleven numbers, each a scientific paper, and a twelfth number, which gives the record of the society and various information concerning the Academy. This volume will contain, when completed, somewhere about 250 pages. This has been done during the year which is just closed, and I am glad to be able to announce that the Council has decided,— with some trepidation, it is true, but still with the purpose of carrying out the plan if it is possible to do so, — to publish an annual volume, a thing which has never been done before by this Academy. The practice has been to publish each paper as ordered by the Council, and, when enough pages had been printed, to close the volume. We have now decided to made a slight change in the manner of publication and to close each volume at the end of the year. This will make the volumes not exactly of the same size, but approximately so. I regard this as a very decided step in advance; but of course it remains for the members of the Academy and others interested to assist in the work, to enable us to do this. It is, however, another source of congratulation to know that never in the history of this Academy, from the eartiest time until now, has a suitable paper been offered, and accepted by the Council, which means have not been at hand or presently found to publish; and I am glad to say that we are still in that pleasant situation, ready to publish any good material that is offered.

I therefore think that, looking at the situation of the Academy as it stands at present, we have every reason for congratulation. Effort must be made, not only to retain the present membership but to increase it, to interest scientific workers in the advantages of the Academy, to let them know that there is a means for publishing their work; and such results cannot be achieved without effort, particularly in a busy commercial town like ours. But I feel confident that the future will take care of itself if the earnest workers that we have in our midst will continue in the work simply of adding to scientific knowledge and of spreading that knowledge whenever they have the opportunity.

I need not say that I fully appreciate the compliment and the responsibility of election for another year.

The Treasurer reported as follows: —

RECEIPTS.

Balance from 1897	$ 603 41	
Interest on invested money	379 16	
Membership dues	1,515 00	
Invested capital returned	1,000 00	$3,497 57

EXPENDITURES.

Rent	$ 450 00	
Current expenses	254 52	
Publication of Transactions	677 67	
Capital invested [including accrued interest]	1,410 50	2,792 69
Balance to 1899		$704 88

INVESTED FUND.

Investment on security	$6,400 00

After the Treasurer's report had been read, the President called attention to the mention of an increase in the invested fund from $6,000 to $6,400, and remarked that this was a larger sum than had ever before been invested, adding: —

"I wish also to call attention to this point, which I forgot to mention when I was on my feet, namely, that small donations for the permanent fund will probably be as useful, and can be obtained with perhaps as little effort, as any contributions that could be received for the Academy. We cannot expect that the invested funds will grow very rapidly, but, if we succeed in increasing them even four or five hundred dollars per year, we shall soon have a very respectable income without relying wholly or even in part upon the dues of members."

The Librarian reported that during 1898 exchanges had been received from 276 societies, of which five had this year been added to the exchange list. In all 941 numbers were reported as having been added to the library, an increase of 104 as compared with the preceding year. It was reported that during the year the Transactions of the Academy had been distributed to 527 societies or institutions, chiefly by exchange or donation.

A METHOD OF MEASURING THE PRESSURE AT ANY POINT ON A STRUCTURE, DUE TO WIND BLOWING AGAINST THAT STRUCTURE.*

Francis E. Nipher.

Various investigations on wind pressures have been made from time to time, by methods which differ essentially from each other. In one form of pressure recorder, an open tube has its mouth directed to the wind by a vane upon which the tube is mounted. The leeward end of the tube connects with some device for measuring the pressure of the air within the tube. This method has been used for a century.

Newton's idea of this device is very well known, and wind gauges of this kind have been much used. The air stream may be supposed to flow from a reservoir of air of the same density, and having a height h. If the density be δ the pressure in dynes per square cm. which would cause the supposed efflux at velocity v is

$$P = g\,h\,\delta.$$

The velocity of efflux is

$$v = \sqrt{2\,g\,h}.$$

Eliminating h

$$P = \frac{\delta}{2}\,v^2. \qquad (1)$$

If v is given in centimeters per second, and δ be given in grammes per cubic centimeter, then P will be given in dynes per square centimeter. At ordinary temperatures and pressures, δ may be taken as 0.0012. If v be in miles per hour and P be in lbs. per square foot,

$$P = 0.0025\,v^2. \qquad (2)$$

* Presented to The Academy of Science of St. Louis, December 20, 1897.

An obstacle which wholly checks the wind, would develop this pressure on its windward surface.† This is the pressure collected by an open tube directed by a wind-vane. I have verified this formula by experiments on railroad trains and find it very exact.

In pressure-board work, the experimenter determines by means of calibrated springs, the total force required to hold the board against the wind, and divides this force by the area of the board. This gives an average pressure. And here the result is due to a summation of compression on the windward side, and rarefaction on the leeward side. In the tube collector, the effect of rarefaction is wholly eliminated.

It is not uncommon to hear statements that the want of agreement of different observers in their determination of the constant in eq. (2) is very unsatisfactory. Part of this disagreement is due to the fact, that the phenomena were essentially different.

Neither the tube collector nor the pressure-board yields any information of value concerning the distribution of wind-pressures over buildings or other structures. It is this information which the writer has sought to obtain.

The pressure of the quiescent air in a building, against the inner surface of its walls, is given by a barometer. In a wind storm, the air masses surging against the building, and sweeping around it, compress the air on the windward side, and produce a rarefaction on the leeward side. These differences in pressure are continually changing, as the wind velocities change, and they are continually dissipating by a flow of air into and out of the building. This flow takes place, not only through windows, doors and crevices, but apparently through heavy brick walls and plastered interiors. I have found by methods that will appear later, that in a tightly closed brick house, the effect of wind is to increase the pressure within the building. This was the case when windows and doors were provided with weather strips, and two stoves were burning on the first floor, and an open grate fire was burning on the second floor where the internal pressure was taken. The air was rushing upward in the chimney leading from the open grate with such velocity as to yield the fluttering sound which

† Newton's Theorem.

was almost on the point of breaking into a deep musical note. And still the pressure within the building was increased by every increase in wind velocity. Within the building the barometer measures the air pressure, modified by these wind effects.

If however we take the barometer outside of the building, where it is exposed to the wind, it fails to measure the true pressure of the air. The barometer is then an obstacle in the wind. Some of the small openings leading into its air-spaces may collect pressure from compressed air on the windward side, and some from the rarefied air on the leeward side. In addition the air sweeping across the mouths of such openings produces rarefactions within, by an action which is utilized in the atomizer. The barometer will then record the resulting air-pressure within its air spaces, just as inside the building it measures the air-pressure in the building. But this gives no indication of what the pressure is outside of the barometer. If we shield the barometer from the wind by inclosing it in a box or casing, then we have simply placed it in another house. The air-spaces of the box are then in the uncertain condition which existed before in the barometer.

The device which is to be used for measuring the pressure at any point on a building, must consist of a collector, to be placed at the point, and an indicator or gauge, to be placed at any point where convenience demands, and a tube for transmitting the pressure from collector to gauge.

The collector must be small and portable. It must be unaffected by the wind, but must collect and transmit changes in pressure due to wind. Compressions and rarefactions due to the collector itself, must not be allowed to affect the gauge. The suction or atomizer action of wind blowing across the end of a tube must also be prevented.

After many failures the collector shown in Fig. 1 was devised, and seems entirely satisfactory. The tube leading from the pressure gauge, and shown in longitudinal section, pierces a thin circular disk, having a diameter of $2\frac{1}{2}$ inches. The end of the tube is flush with the face of the disk. The disk is ground to a thin knife edge as shown. A second disk of the same size is screwed down upon the former.

The screw head should be soldered or brazed to the second disk, in an air-tight joint. The screw threads are held in a perforated nut brazed into the end of the tube.* Between the disks is clamped a circular, porous layer, which extends half an inch or more outside of the metal disks. The material best suited to use in this porous layer seems to be wire screen. I have tried the finest brass wire cloth, having 130 wires to the lineal inch, and ordinary iron window screen, having 12 wires to the inch. The number of thicknesses of screen has been varied from two to twelve. The results were not appreciably affected by such changes. For use in rain storms the coarse iron wire is to be preferred. Three sheets of wire screen, making angles of 30° with adjoining sheets, give very

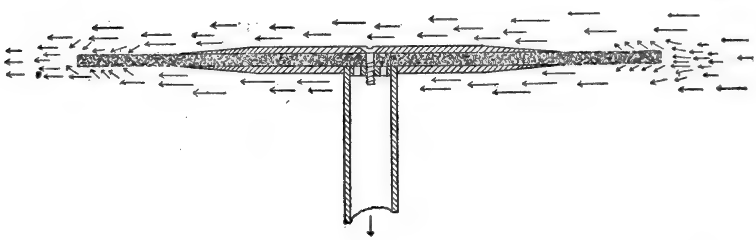

FIG. 1.

satisfactory results. The wire may be dipped into a thin oil, in order to prevent water from clogging the layer. When the fine wire is used, the central part of the layer around the screw should be punched out to form an air chamber.

According to the plan which dictated the design of the collector, it was to be unaffected by wind, when placed edgewise in the air current. The air currents between the two disks are so checked that no atomizer action is possible. The compression on the windward edge of the porous layer, is dissipated by lateral outflow before it penetrates between the metal disks. The rarefaction on the leeward edge is similarly prevented from affecting the air between the disks. This is accomplished by a lateral inflow of air. The arrows in Fig. 1, roughly indicate the action described. This collector was placed under a bell-jar resting on a glass plate. The tube led

* Soldered joints will serve unless the collector is to be used in the hot air of a chimney.

out through a stopper, and was taken to the air space in a cistern half full of water. The capacity of the cistern was about 100 cubic centimeters. From the bottom of the cistern, a glass tube one meter long, and having an inclination of 5 in 100, served as a gauge for indicating air pressures in the cistern. A second tube entered the stopper of the bell-jar. The effect of breathing gently into the mouth of this tube, and producing a slight compression of the air in the bell-jar, is instantly seen in a rise in the water column of the gauge.

In order to test the collector in a high wind the apparatus was taken upon a passenger car. The water gauge was clamped to a window sill. The doors were opened at each end of the car. The ventilators and windows were also opened, so that there was a free circulation of air through the car. There was no appreciable atomizer action on the gauge. The collector was thrust out of the window, and held edgewise in the wind at a distance of thirty inches from the side of the car. The connection between collector and gauge was then made and broken. No effect was produced on the gauge. This experiment has been repeated at various times, and in one case when the train traveled between two stations fifteen miles apart in fifteen minutes by the watch. When the hand is placed tangent to the windward or leeward edge of the collector, the gauge at once shows a marked decrease or increase in pressure. The wind in free air does not affect the gauge, but any change in pressure is at once indicated. It was also found that the collector might be held in any other position in the wind, with no appreciable change in the result.* The wire layer was cut off even with the edge of the metal disks. When placed edgewise in the wind, a marked increase in pressure was then shown. When turned $7\frac{1}{2}°$ around a diameter at right angles to the lines of flow, this increase in pressure disappeared. For greater angles the gauge showed an exhaust.

The disk collector thus appeared to satisfy all of the requirements, and justified more serious attempts to test its limitations.

* This has only been tried with the fine brass wire, but with from two to twelve thicknesses.

From what has been said it is apparent that the open leg of the water gauge should be connected with some standard pressure, and not allowed to communicate with the air in the room. The method suggested by Abbe was employed.*

Two thin circular steel plates eighteen inches in diameter were ground to a sharp beveled edge. They were clamped together and held rigidly one-eighth of an inch apart, by four screws near the edge having accurately turned bushings between the plates. A small screw was also used to clamp the plates near the center, in order to prevent vibrations of the plates. A face plate was screwed to the center of one plate into which an iron pipe could enter, and which served as a vertical support for the plates. Inside of the pipe a rubber tube made connection with a small brass tube which pierced the large plate flush with its surface. This device is placed above the building in the undisturbed stream of air, with the plane of the disks horizontal. The tube terminating between the two disks was connected with the inclined leg of the pressure gauge. The cistern of the gauge was connected with the collector shown in Fig. 1. This collector was mounted above the building near the other device. When the large disks were as near as one-eighth of an inch it was found that the two collectors balanced against each other perfectly, in the strongest winds of last winter. The conditions of steady flow of a fluid between two large plates have been discussed by Sir William Thomson.† Abbe states the result as follows: "Steady motion becomes easy and turbulent motion becomes difficult when the distance between the plates is equal to or less than the diameter of the plates, multiplied by the ratio — coefficient of viscosity of the air, divided by coefficient of skin friction of the air on the plate.

"The pressure of the air within the tube is then the same as that between the plates, and in the free air around them."

When the cistern of the gauge was allowed to open into the air of the room, the variation of pressure within the building, due to gusts of wind, was plainly shown.

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* Report of the Chief Signal Officer, 1887. 2: 144.

† Phil. Mag. Sept. 1887, and verbally at the Manchester meeting of the British Association. See Report of the Chief Signal Officer before referred to.

With a view of making a further test of the disk collector of Fig. 1, it was decided to make a study of the distribution of wind pressure over a large pressure board, carried above the roof of a railway car. The President and the General Superintendent of the Illinois Central Railroad readily consented to co-operate with us, and furnished a car which was changed to adapt it to the work. The shops of the road at East St. Louis and Centralia, Illinois, were practically placed at our disposal, and the apparatus, which had been constructed in the shop of the Physical Laboratory of Washington University, was sent to the railroad shops, and mounted upon the car.

The pressure board was three feet wide in vertical dimension, and four feet long. It was made of dry pine seven-eighths inch thick, the wood having been boiled in oil, in which it was allowed to cool. In this way it was hoped to prevent warping due to sun and rain. The boards were grooved together, and were bound at the top and bottom by cross pieces of wood in the plane of the board. The board was provided with two strap hinges of iron, one-fourth of an inch thick, four inches wide, and crossing the entire board. They covered the horizontal strips marked *b* and *h* in Figs. 3 and 4.

The hinges were each bolted by twelve $\frac{3}{8}$ inch bolts at the center of the four inch squares shown in the figures.* The hinges extended beyond the board and locked to a vertical iron pipe one and five-eighths inch external diameter which passed down through the roof of the car to the floor. The board was mounted upon the pipe somewhat as a flag is mounted upon its staff. The distance from the edge of the board to the center of the pipe was six inches, the clearance between board and pipe being intended to isolate the board from the pipe. The hinges were only an inch wide in vertical dimension where they crossed this interval, but were made broader laterally. The lower edge of the pressure board was one foot above the center of the roof.

The pipe turned on ball bearings at the bottom, capable of taking up any thrust in a vertical or a horizontal direction.

* The pressure board is not shown to scale in these figures, since the small areas are not squares.

A similar ball bearing surrounded the pipe at the roof. The pipe was clamped in collars near the floor and roof, and tension rods spread out from collar to collar, passing over compression members, which braced against the pipe in order to stiffen it in the plane of the pressure board.

The vertical pipe was provided with a T into which a horizontal pipe was screwed to serve as a lever. A spring-balance was attached to this lever on an arm of 36 inches. The spring balance rested on a horizontal shelf, forming part of a movable windlass around which a small rope attached to the ring of the spring balance was wound. From the hook of the balance, a wire was attached to the lever arm. A graduated arc attached to the lever under this wire showed the angle between the normal to the lever, and the direction of the pull indicated by the spring balance. This angle was kept small by moving the windlass, but the angle was read whenever the balance reading was taken. The board turned so easily that its friction was wholly inappreciable. The pressure board could be set at any angle with the wind, and the moment of the force required to hold it there was determined.

The setting of the board was accomplished by means of a wind vane near the front of the car mounted in ball bearings exactly like those of the pressure board. Pointers a foot in length clamped to the pipes of pressure board and wind vane moved over graduated scales. They were set to 180° on both scales, when vane and board were set in a head wind coinciding with the axis of the car. A second movable pointer on the pressure board circle could be set to any desired angle with the former. Bringing this pointer to the scale division indicated by the wind vane pointer, would set the pressure board to the desired angle with the wind.

In that part of the work of which account is here given, this angle was 90°. The pressure board was then at right angles to the wind.

In a head wind, the vane was very steady, but when the wind blew strongly across the car, there was always more or less of fluctuation, and the pressure board was held in a mean position, and favorable conditions were seized upon as they presented themselves.

The work of setting the pressure board, reading the position of the wind vane, the index of the spring balance and the angle of pull, was done by Professor A. H. Timmerman, formerly my assistant, and now Professor of Physics in the Rolla School of Mines. It was necessary to give constant attention to all of the indications to be read, in order that values practically simultaneous could be obtained when an adjustment was secured.

The pressure board was divided into 108 four-inch squares. The vertical rows of squares were numbered from 1 to 12, the former being nearest to the axis of rotation. The horizontal rows of squares were lettered from *a* to *i*, the former being at the top. At the center of each square a hole ⅜ of an inch in diameter was bored through, and two disk collectors could be mechanically coupled to each other through any one of them so as to close it in an air-tight joint. All other holes were closed by closely fitting corks, flush with the front side of the board. One collector was furnished with a screw, which was seated in a screw hole in a hub attached to the other collector, and fitting into the hole in the pressure board. The manner of mounting these collectors is shown in Fig. 2, where the fragment of wood between represents the pressure board. Rubber tubes passed down through the iron pipe into the car and connected the disks on the front and rear of the pressure board with separate pressure gauges. In this way the pressure could be determined at 109 different points on the board, the pressure in front being measured separately from that on the back of the board.

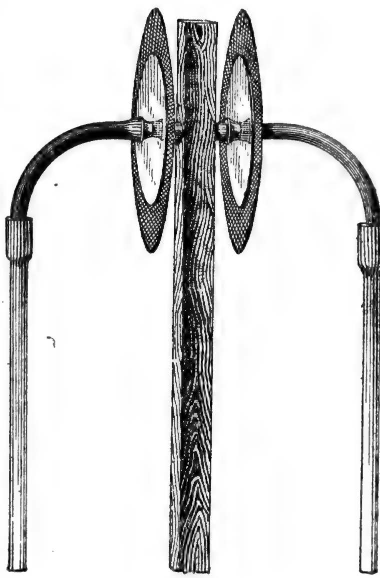


FIG. 2.

The pressure gauges were four in number. The cisterns were

2½ inches in diameter and 4 inches high. The glass tubes leading out from the bottoms of the cisterns were all mounted in parallel grooves in a board graduated to centimeters, from 0 to 100. The cisterns had a vertical screw adjustment, so that the water levels could all be set to 40 centimeters on the scale. The tubes were all inclined 5 in 100. The support for the tubes was set in a longitudinal position in the center of the car and was provided with a pivotal adjustment in leveling on varying grades. A spirit level was used in adjusting the level when the car was at rest, but during motion of the train, one of the three gauges was used as a level, its scale reading being maintained at 40. The tube and cistern of this gauge were closed on each other by a rubber tube. The gauges were mounted on a pendulum weighing about 150 pounds, suspended on knife edges from the roof of the car, and swinging transversely. A paddle at the bottom dipped into a trough containing fifty pounds of crude glycerine. This paddle was adjustable as a valve, so that the time of swaying of the pendulum could be adjusted to the rocking of the car. It was, however, necessary to constantly steady and check violent swinging with the hand. By this means, however, a very satisfactory leveling was maintained. See Plate 1.

The cistern of the third gauge was connected with an open cup collector attached to the wind vane two and a half feet above the center of the car. The vane consisted of light diverging wings of wood, three feet in vertical dimension and two and a half feet long. The vane was 16½ feet from the pipe supporting the pressure board and the pipes supporting vane and pressure board were five feet two inches from the side of the car. When free in the wind, board and vane always set parallel to each other, and in a calm, they set parallel to the axis of the car when the train was in motion. When the pressure board was set at right angles to the car, its center was in the middle vertical plane of the car. The car was reversed at the end of each run, so that the vane was always in front. The external mounting is shown in Plate 2.

The three gauge tubes were separately connected by rubber tubing with an iron tank fifteen inches in diameter and twenty-eight inches high, which was connected by a large rubber hose with the Abbe collector before described. The latter was exposed above the roof of the car. It was placed symmetrically opposite the wind vane, and 38 inches above the roof. At all points where rubber tubing might become sharply bent, a connection of brass pipe was inserted. This pipe was bent into a smooth curve by first filling it with lead. The tubes were all adjusted so that gauge columns would respond with equal promptness, when they were affected by a common pressure change. The iron tank containing the common standard pressure against which all pressures were measured, was made large enough, so that a rise to the gauge limit affecting only one gauge would not appreciably affect the others.

The resistance of the fine brass wire cloth in the collectors, was found to be equal to that of 20 to 25 feet of the rubber tubing used in connecting. This was determined by a method equivalent to a Wheatstone bridge arrangement. A divided circuit consisting of two equal tubes led from a common source at an air blast to the extremities of a long horizontal glass tube, which drooped in the middle and contained a short column of water as an index. The other two arms of the bridge consisted of the disk collector, and a tube whose length was so chosen that the pressures on the water index were balanced when an air blast was applied. These circuits were "grounded" in the air. The final adjustment on the car was, however, made by trial, by blowing gently for a moment into the tank. This adjustment was effected by means of screw clamps, which pinched the rubber tubing connecting the cisterns and the gauge tubes. See Plate 1.

The gauge readings were all made by myself. The instrument was kept constantly leveled and steadied, and on a call of "read" from Mr. Timmerman, the three gauges were simultaneously determined. The columns vibrated constantly through two or three centimeters, and it was necessary to be always ready to take an average reading of them all. Two wooden pins were set on the divisions to be read on two of the scales, and the third was read first. The other two were then read later. All of the work was recorded by Mr. Louis Schlossstein, of St. Louis, who also made a simultaneous reading of train speed, as shown on the dial of a Boyer speed recorder.

The work was all done on the Illinois Central Railroad between Champaign and Centralia. The car was the second car from the locomotive in the fast freight trains running between Chicago and New Orleans. The start from Champaign was made at 5:35 a. m. and Centralia would be reached at 11:50 a. m. Sometimes we made the return trip in the afternoon, starting from Centralia at 2:45 p. m. and reaching Champaign again at 9:00 p. m. The work during the latter part of this run was done by the light of caboose lamps. The double run proved too much for our endurance, and we were generally satisfied with the single run. The speeds varied from 20 to 50 miles per hour, as shown by the recorder. The indications of the recorder were checked by watch observations on the mile posts. We found a small index error which could easily have been corrected by an adjustment of the driving pulley of the instrument, but we preferred to make no change.

The experiments were begun on June 26, 1897, and were continued every day until July 20, although part of this time was devoted to work not within the scope of this paper.

About 1,500 independent measurements were made upon the pressure board. It was decided to make a very thorough determination of pressures along the middle lines of the board. Such observations were made along the horizontal line of squares from 1 to 12, *e*, Figs. 3 and 4, and along the two vertical rows *a* to *i*, 6 and 7. In addition the half of the board furthest from the axis was well explored, and observations were made at a few symmetrically located points in the other half of the board in order to detect any substantial difference which might exist. It was to have been expected that slight flexures of the board might result in some differences in the lateral halves, although no appreciable difference was found. It was however found that the dragging of air along with the train caused the pressures on the front side to be greater at the top than at the bottom of the board. This effect was least when strong winds blew across the trains. It was also found that the rarefaction was greater near the bottom than near the top on the back side of the board. This was doubtless due to the obstructing effect of the car roof.

Fifteen observations of pressure in any square were usually taken at one time and the collectors were then removed to another. In the tables which follow the means of these observations are given. Where several determinations are given for the same square, they were usually made on different days. Some discrepancies appear which seem too large, but all observations have been included. The tremendous shocks which our improvised laboratory sometimes received made it necessary to exercise constant vigilance in detecting loose adjustments, and some sources of error have doubtless escaped us.

It was found that increase of pressure on the front side of the board, and decrease of pressure on the back side were linear functions of the total force required to hold the board to the wind, as measured by the spring balance. If F represent the pull of the spring balance on an arm of 3 feet, h_1 the increase in the scale reading of gauge No. 3 above the datum reading, 40.0 and h_2 the decrease of gauge reading of No. 4, below 40.0, then for the front and rear pressures we have respectively,

$$h_1 = A_1 F$$
$$h_2 = A_2 F$$

where A_1 and A_2 are constants A_2 being essentially negative. They denote the increase or decrease of scale reading per pound of pull on the spring balance. A_1 and A_2 are reduced to vertical water column by multiplying by 0.05. This may be taken as the pressure in grammes per square centimeter. The correction for density of water is about half of one per cent., and is slightly overcompensated by the change of level in the cistern. The further factor 2.048 reduces the pressures to lbs. per square foot. The factor for reducing A_1 and A_2 to lbs. per square foot is therefore 0.1024.

The values of A_1 and A_2 have been entered in the proper squares on diagrams of the front and the back of the pressure board. Such diagrams are shown in Figs. 3 and 4. The board was divided into strips where the conditions were evi-

	1	2	3	4	5	6	7	8	9	10	11	12
a	4.00	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.00
b	4.30	5.00	5.90	5.94	5.94	5.94	5.94	5.94	5.94	6.00	5.90	3.99
c	4.30	5.94	6.50	6.96	6.96	6.96	6.96	6.96	6.96	6.20	6.14	3.99
d	4.30	5.94	7.48	6.90	7.48	7.48	7.48	7.48	6.96	6.55	6.14	3.99
e	4.30	5.94	7.48	6.96	7.17	7.17	7.17	7.17	6.96	6.55	6.14	3.99
f	4.30	5.94	7.48	7.00	7.48	7.48	7.48	7.48	6.96	6.55	6.14	3.99
g	4.30	5.94	6.50	7.37	7.37	7.37	7.37	7.37	7.37	6.30	6.14	3.99
h	4.30	4.20	5.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	3.99
i	3.00	3.28	3.28	3.28	3.28	3.28	3.28	3.28	3.28	3.28	3.28	3.30

FIG. 3.—FRONT OF THE PRESSURE BOARD.

a	3.00	3.58	3.58	3.58	3.58	3.58	3.58	3.58	3.58	3.58	3.70	3.00
b	4.30	4.40	4.00	4.00	4.00	4.06	4.00	4.00	4.00	4.00	4.00	3.99
c	4.30	4.61	4.70	4.20	4.20	4.20	4.20	4.20	4.20	4.10	3.99	3.99
d	4.30	4.61	4.91	4.40	4.30	4.30	4.30	4.30	4.60	4.61	3.99	3.99
e	4.30	4.61	4. 91	4.61	4.61	4.61	4.61	4.61	4.81	4.61	4.61	3.99
f	4.30	4.60	4.70	4.61	4.61	4.61	4.61	4.61	4.61	4.80	4.61	3.99
g	4.30	4.60	5.00	5.02	5.02	5.02	5.02	5.02	5.02	4.80	4.60	3.99
h	4.30	4.50	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.50	3.99
i	4.20	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.00	3.50
	1	2	3	4	5	6	7	8	9	10	11	12

FIG. 4.—BACK OF THE PRESSURE BOARD.

dently similar, and the average of observed values made in this area was determined. Thus, in the row of squares adjacent to the edge, the top line of squares constitutes such an area. These squares are marked 1 to 12, *a*. The line of squares 1 to 12, *i*, is another such area. The averages in the vertical rows *a* to *i*, 7, and *a* to *i*, 12 were also separately found.

The average value for such areas was then entered in all the squares of the areas, excepting that the values in the corner squares were smoothed a little, in order to make adjoining side rows unite with each other. Over these corner squares the pressures diminish in two directions toward the nearest edges of the board. In such cases the integrated pressures must therefore be less than in squares removed from the corners.

In like manner the averages in the second row of squares from the edges were determined. In this row the squares 2 to 11, *b*; 2 to 11, *h*; *b* to *h*, 2; and *b* to *h*, 11 were separately treated. The data contained in the table may be used by anyone to repeat these computations. The results for each square on the board are entered in Figs. 3 and 4, where the values have all been multiplied by 100. The values in Fig. 4 are of course negative in sign. These values therefore correspond to a spring balance reading of 100 lbs., when the arm is three feet. The moments of the forces applied to these four-inch squares with respect to the axis of rotation have been summed. It was assumed as sufficiently exact, that the center of pressure for each square of $\frac{1}{9}$ square foot, was at its center. The arm for the vertical row *a* to *i*, 1, is $\frac{2}{3}$ ft., the arm for vertical row *a* to *i*, 2, is one foot, etc. The sum of the moments for the front and back sides of the board was found to be, —

Front	169
Back	128
Total	297
By the spring balance	300
Difference	3

A difference of one per cent.

Square.	A_1	A_2	Square.	A_1	A_2
1 *a*	0.36	—0.41	7 *g*	0.85	—0.37
1 *e*	0.33	—0.46	7 *i*	0.23	—0.48
"	0.45	—0.36	"	0.36	—0.40
"	0.50	—0.38	8 *e*	0.73	—0.36
1 *i*	0.44	—0.48	"	0.67	—0.44
2 *e*	0.56	—0.47	9 *a*	0.43	—0.44
"	0.61	—0.42	9 *c*	0.70	—0.41
3 *c*	0.80	—0.51	9 *d*	0.68	—0.46
3 *e*	0.63	—0.46	9 *e*	0.65	—0.51
"	0.62	—0.44	"	0.66	—0.42
3 *g*	0.86	—0.51	"	0.72	—0.49
4 *e*	0.66	—0.45	9 *f*	0.67	—0.48
"	0.71	—0.44	9 *g*	0.63	—0.49
5 *e*	0.66	—0.41	9 *i*	0.20	—0.46
"	0.61	—0.48	10 *a*	0.40	—0.37
6 *a*	0.48	—0.35	10 *c*	0.51	—0.36
"	0.44	—0.30	"	0.61	—0.44
"	0.43	—0.33	10 *d*	0.67	—0.43
"	0.42	—0.29	10 *e*	0.52	—0.49
"	0.45	—0.35	"	0.66	—0.44
6 *c*	0.74	—0.43	"	0.72	—0.44
"	0.67	—0.44	10 *f*	0.76	—0.34
"	0.66	—0.36	10 *g*	0.50	—0.53
6 *d*	0.76	—0.41	"	0.80	—0.56
"	0.65	—0.43	10 *i*	0.30	—0.48
6 *e*	0.63	—0.43	11 *c*	0.62	—0.44
"	0.65	—0.54	11 *e*	0.63	—0.45
6 *f*	0.73	—0.30	"	0.50	—0.39
"	0.70	—0.46	"	0.53	—0.52
6 *g*	0.48	—0.54	"	0.55	—0.46
"	0.80	—0.40	11 *g*	0.77	—0.45
6 *i*	0.22	—0.51	12 *a*	0.13	—0.39
"	0.38	—0.40	12 *d*	0.34	—0.41
"	0.37	—0.34	12 *e*	0.46	—0.40
7 *a*	0.51	—0.31	"	0.52	—0.36
"	0.55	—0.35	"	0.34	—0.43
7 *c*	0.70	—0.39	12 *f*	0.52	—0.45
"	0.77	—0.34	12 *i*	0.40	—0.36
7 *d*	0.65	—0.47	Center.	0.81	—0.47
"	0.90	—0.35	"	0.70	—0.46
7 *e*	0.56	—0.48	"	0.83	—0.41
"	0.78	—0.41	"	0.80	—0.36
7 *f*	0.68	—0.58	"	0.77	—0.40
"	0.87	—0.41	"	0.64	—0.49
7 *g*	0.65	—0.52	"	0.65	—0.57

The sum of the 108 values for pressure on the front side, each multiplied by the area to which it applies, viz.: $\frac{1}{9}$ foot, is 66.98 lbs. For the back side it is 51.76 lbs. The total force to be applied at the center of pressure is therefore 118.7 lbs.

For the location of the center of pressure, we have for the front and back sides, respectively,

$$\text{Front, } \frac{\Sigma\, Fl}{\Sigma\, F} = \frac{169}{67.0} = 2.52.$$

$$\text{Back, } \frac{\Sigma\, Fl}{\Sigma\, F} = \frac{128}{51.8} = 2.47.$$

The center of pressure for the front side of the board is in vertical row 7, and 0.02 feet from the middle line of the board. For the back side it is in row 6, and 0.03 feet from the middle line. These pressures would therefore practically balance on the middle line.

Summing the moments of the pressures with respect to the upper edge of the board, the center of pressures is likewise found to be below that edge a distance,

For the front side 17.1 inches.
For the back side 18.6 inches.

On the front side, the center of pressure is above the middle horizontal axis, a distance 0.9 inch, while for the back side, the center of pressure is below that line by 0.6 inch.

The resultant center of pressure is therefore slightly above, but very near the center of the board.

The completeness with which the indications of the collector and gauge check against the spring balance, is doubtless due in some degree to accident. It may be worthy of remark that the first reduction gave for the sum of the moments over the board a value 340 instead of 297 as before given. The reduction of all the original observations was then repeated, and the distributed pressures shown in Figs. 3 and 4 were carefully considered. There appeared to be no justification of any change which could affect the result by more than a fraction of one per cent. After several unhappy days, in which the advisability of publishing anything concerning the disk collector was under serious consideration, it was finally discovered that in reducing from grammes per square centimeter to lbs. per square foot, a factor 0.1174 had been used, instead of 0.1024.

An inspection of Fig. 3 will show that there is some evidence of a minimum of pressure at the center of the front face. This may be due to the effect of the hinges which cover the horizontal rows *b* and *h*, although this is not regarded as very probable. It is not probable that this is wholly due to errors in observation.

The results shown in Fig. 3 also furnish a method of determining a value of considerable historical and theoretical interest. The average pressure on a board held normally in any fluid stream, due to the compression on the front and rarefaction on the back side, is

$$P' = K \frac{\delta}{2} v^2 \qquad (3)$$

instead of being represented by (1). The value K is independent of any friction or viscosity in the fluid. It is the same for water as for air. It involves simply inertia in resisting a change of direction in passing the edge of the plate. Many determinations of this value have been made. In some cases in which the stream was water, the pressures before and behind the board have been measured by pressure columns.*

The values obtained by various experimenters are given in a table. The rotation experiments of Borda, Hutton and Thibault are said by Unwin to have been made on a long arm, but the lengths are not given. In Langley's experiments, the radius was 9 meters. His result is the mean of 14 determinations made with an automatic recorder.

If we may assume the value 7.17 lbs. per square foot at the middle of the front side of our pressure board (Fig. 3) to be the pressure due to the velocity with which the board moves through the air, computed by Newton's theorem, we

* Hydromechanics. Encl. Brit. 517.—Report Chief Signal Officer, 1887. 2:223.

may then determine K. The total effective force against the plane, we have found to be 118.7 lbs. Since the area was 12 sq. ft. the average pressure is 9.89 lbs. per sq. ft. Hence $K = 9.89 \div 7.17 = 1.37$.

K	Authority.	Medium.	Area of Plate sq. ft.	Remarks.
1.39	Borda	Air	0.13	Rotation.
1.49	"	"	0.25	"
1.64	"	"	0.63	"
1.24	Hutton	"	0.13	"
1.43	"	"	0.25	"
1.525	Thibault	"	0.25	"
1.784	"	"	1.11	"
1.433	Dubuat	Water	1.0	Still Water rect. $v = 3$ to $6\frac{1}{2}$ ft. per sec.
1.36	Morin Piobert & Didion	Air	0.3 to 2.7	....
2.18	"	Water	"	Vertical motion shallow tank.
1.25	Mariotte	"	....	....
1.856	Dubuat	"	....	Plate stationary, stream of water.
1.834	Thibault	Air	1.17 to 2.5	Wind Power.
1.31	Langley	"	1	Rotation $v = 4$ to 11 meters per sec.

The pressures in Fig. 3 correspond to a balance pull of 100 lbs. on an arm of 3 ft. This is equivalent to a force of $(3 \div 2.5)\ 100 = 120$ lbs. at the center of pressure. The pull per square foot is therefore 10 lbs. This gives a value for K of $10 \div 7.17 = 1.39$. This value is only in part determined from data independent of that involved in the other determination.

If instead of taking the pressure at the middle of the pressure board we take the average pressure over the front face, we have by the spring balance determination of pull, $K = 10 \div 5.58 = 1.79$, which agrees very well with some of the higher values of K determined by others. It is however evident that this value of K is theoretically a wholly different quantity from that which we seek to determine.

It seems entirely possible that the pressure at the center of the board is less than that which corresponds to the average $(\text{velocity})^2$ with which the wind sweeps past the board, as computed by the Newton theorem. The determination of this wind velocity is a problem of much greater difficulty than at first sight may appear. If we assume 7.48, the highest pressure on the board to correspond to this velocity, the value of K becomes $10 \div 7.48 = 1.34$.

The spring balance and pressure collector deal with the pressures which really affect the pressure board, regardless of the complexity of air currents. In this respect they differ essentially from the tube collector attached to the wind vane.

In illustration of this point I may relate one incident of our work which happened after our pressure board work was finished. It was observed on starting on one of our trips, that the gauge attached to the cup collector on the wind vane showed little if any increase in pressure. As the speed increased, it began to show an exhaust, which seemed to increase with the speed. Every part of the pressure circuit was examined and no cause could be found for the result. Finally it was observed that unnoticed by us, a refrigerator car had been placed in front of us, and it was thought possible that the open trap-door in the roof of this car might be the cause of the trouble. The door was 33×35 inches, and was opened to an angle of 33°. Its distance from the wind vane was eleven feet. The door was shut down, and the gauge reading increased 20 centimeters in a couple of seconds. This door had deflected the air stream upwards, and it had descended in a cascade upon our car. The lines of flow must have made a somewhat greater angle than 60° with the horizontal axis of the tube collector. It is because of such experience that no use has been made of a great mass of data involving velocities. This material will be used in a future paper, dealing with the effects of the train upon the air around it.

The results of this investigation seem to fully justify the use of the disk collector in a study of the distribution of pressure on large buildings. An arrangement which I have found very satisfactory may be briefly described. A window is raised a couple of inches, and a wooden bar capable of longitudinal extension is placed in the opening thus formed. A $\frac{3}{8}$ inch brass tube connecting with the pressure gauge passes out through a hole in the bar. Outside, this tube enters a similar tube at right angles to the former, and forming the arms of a T. From the ends of these arms short tubes return to the wall of the building, and serve as feet for holding the conducting tube in position, when it is pulled into position from within. The ends of the feet should be plugged, and one of them should be adjustable, to provide for inequalities in the wall surface. The end of one arm of the T should also be closed. From the other, a tube extends six or eight inches, and an elbow and tube return towards the building and carry the pressure collector. The plane of the collector is parallel to the surface of the wall, and should be one or two inches from it. Collectors should be placed over the various walls of the building and upon its roof. The tubes should be adjusted to the same resistance, and as nearly as possible, to the same capacity, so that all will respond with equal quickness. The gauge tubes should be parallel and side by side, so that they may be photographed at any instant, when a heavy gust of wind is blowing. The gauge tubes should of course lead into a tank, connecting by a large tube with a large Abbe collector above the roof. This collector should be high enough above the roof to escape the effect of the building. The stream lines should be horizontal where this collector is placed. Near the summit of inclined roofs, on the windward side, and over the entire leeward side, the pressure is reduced by a wind. On a flat roof the pressure is always reduced. The pressure is less than that of the atmosphere, and this reduction of pressure increases with an increase in velocity. The standard pressure should be collected from a point above these disturbances.

When the wind blows at right angles to one side of a building, the pressure on all other sides is diminished. If a window yields on the windward side the pressure within the house will be increased. The tendency is to lift off the roof, and throw three walls outwards. The windward wall is often braced by partitions so that it is less likely to fall in than the others are to fall out. I believe that it is possible to greatly increase the resisting power of ordinary farm buildings against wind without materially increasing their cost.

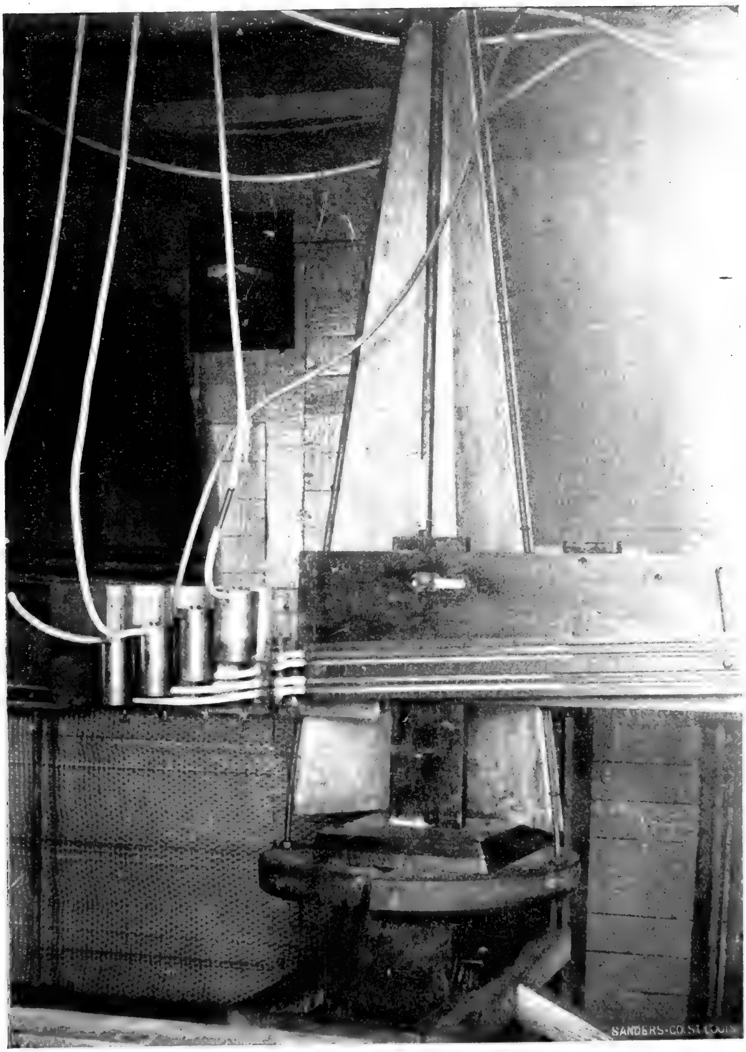
But it is very desirable to determine what these. pressures really are.

The observations on pressures should be supplemented with simultaneous observations on wind directions. A vane with a cup collector connected with a gauge below will determine pressure, due to the free wind, from which velocity may be computed.

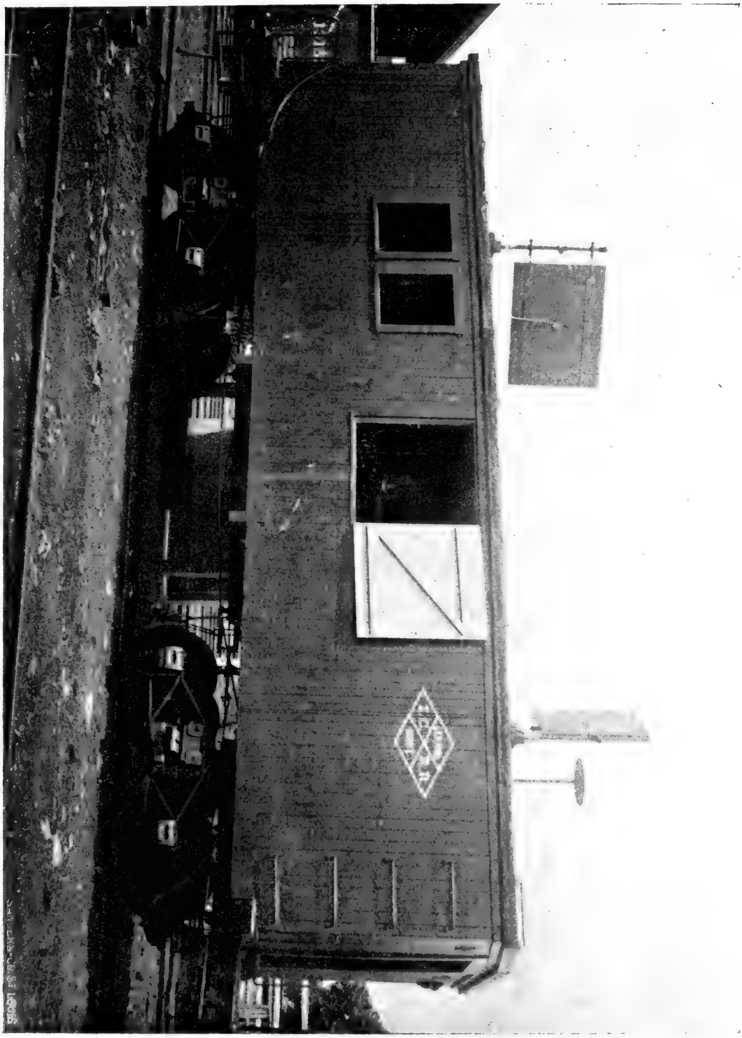
Two metal brushes 180° apart are attached to two insulated rings surrounding the vane-tube. The poles of a battery connect with these rings by sliding contact. A flat commutator with 72 segments surrounds the tube and the two brushes slide upon it, touching opposite segments. The wires lead in a cable to the closed copper windings on an iron ring at the pressure gauges. The wires of the cable connect to these windings at equidistant points, those coming from opposite commutator bars leading to opposite points in the winding, and adjacent wires at the commutator being adjacent at the ring. The arrangement is exactly that of the Gramme armature. The polarity of the ring will follow the shifting of the vane. A magnetic needle whose pivot is at the center of the ring will follow the vane. This needle may be photographed with the scales. With comparatively small expense it will be easy to obtain information of great value, even with ordinary winds. At some of the mountain observatories, destructive winds are not uncommon, and it is desirable that such work should be undertaken there. In conclusion I wish to express my grateful thanks to Professor Timmerman and Mr. Schlossstein for their enthusiastic aid under circumstances which were very far from inviting to one seeking rest and quiet. My thanks are also due to Mr. Stuyvesant Fish and Mr. A. W. Sullivan, President and General Superintendent of the Illinois Central Railroad, through whose co-operation we were enabled to do the work, and to Mr. Joseph Boyer for the loan of his Speed Recorder. There are dozens of others who have assisted us greatly in various ways, whom I cannot name. The names of some of them I do not even know. But it was a constant pleasure to receive their aid, and I feel that much of the success we may have attained was due to such friendly assistance.

On p. 13 reference is made to an uncorrected error in displacement of the zero point. This is a differential error, due to differences in the gauge tubes. The correction is practically all involved in the factor 0.05.

Issued January 14, 1898.



PENDULUM AND PRESSURE GAUGES.



MOUNTING OF THE PRESSURE BOARD.

THE TREES OF ST. LOUIS AS INFLUENCED BY THE TORNADO OF 1896.*

HERMANN VON SCHRENK.

The tornado, which swept over the southern part of St. Louis on May 27th, 1896, was one particularly destructive to the trees and vegetation of that section, and in the following an attempt has been made to enumerate some of the phenomena which followed the period of destruction. On the morning after the storm many of the immediate injuries to trees were noted. Most of the observations were made in the storm center, which included Lafayette Park and the adjoining streets, and observations which follow are to be taken as applying to this region. Norton† has described many of the injuries which the trees suffered, and to these I would add several, necessary to an understanding of the after-effects.

There was hardly a tree which escaped injury of one kind or another, with the possible exception of several cypresses, *Taxodium distichum*, which, with their conical forms, yielded to the force of the wind. The maples and elms, as stated by Norton, were in many cases uprooted, and when this took place in the first few moments of the period of greatest wind velocity, the trees were simply turned over, and when straightened up some days after, resumed their former growth, and to-day these trees are almost the only normal trees in the Lafayette Park district. By far the larger number lost all their principal branches; many were reduced to the trunk with perhaps two forks. The ragged ends of such trunks were sawed off, painted and covered with cloth, and then they looked much like very heavily pollarded trees.

The time at which the injury was done, fell in the period of the tree's greatest activity. The new leaves had not been

* Presented to The Academy of Science of St. Louis, in preliminary form, December 6, 1897.

† Norton, J. B. S. Garden & Forest **10**: 292. 1897.

unfolded for many weeks and many were still unfolding. In accounts of the injuries sustained by trees in former storms, little is said of leaves and leaf injuries. The manner in which leaves are attached to stems enables them to present the smallest surface to the wind, and thus to escape injury. Peculiarities in the structure of leaves have been adduced as another protecting factor.* When moist, leaves are far more liable to injury than when dry; several leaves cling together, and the force of the wind pounds and rubs them against twigs and branches, tearing and lacerating them.† In the present case the destruction of foliage was very marked, particularly in such trees as the soft maples and sycamores; several trees of the honey locust retained most of their leaves. For a large area about the trees, some minutes after the storm, the ground was covered with torn and shredded leaves of all kinds. The leaves were wet, for it had been raining for several minutes before the windstorm, and the injuries evidently were largely due to rubbing against branches. Flying missiles of various kinds aided in the destruction. Grains of sand and small bits of wood and stone, flying through the air at velocities ranging from 50 to 80 miles per hour, were well able to shred the tender leaves. As a result of these combined causes many maples and sycamores were left with hardly a sound leaf on the remaining branches.

Besides the injuries to the branches and leaves there were others not so evident at first. Numerous trees had trunks of sufficient elasticity to bend before the force of the wind, without breaking. In swaying to and fro, the bark on one side was considerably stretched, and compressed on the opposite side, and in the next instant the conditions were reversed. Where this took place repeatedly the bark was torn horizontally for several feet, sometimes on but one side, more often on both. The violent wrenching of a tree with a large top

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* Kny, L. Über die Anpassung der Laubblätter an die mechanischen Wirkungen des Regens und Hagels. Berichte d. deutsch. Bot. Gesellschaft **3**: 207. 1885.

† Magnus, P. Verhandl. d. Botanischen Ver. d. Prov. Brandenburg **18**: viii. 1876. — Caspary, R. Beschädigung der Rosskastanienblätter durch Reibung mittelst Wind. Botanische Zeitung **27**: 201. 1869.

like the maple, produced considerable strain upon the bark, especially when the force applied was a twisting one. Where the strain was too great, the bark came off in sheets, or split longitudinally. This was particularly noticeable in narrow streets like Nicholson Place. In many trees there was no outward sign of this injury for several months; not until the loosened bark died, did any shrinkage take place, but then it split and curled up. This could be seen on many maples in September, 1896. Flying pieces of slate and stone removed large pieces of bark, and often became imbedded in the wood. Wounds of this nature healed rapidly, and many pieces of slate are to-day surrounded by new wood.

Immediately after the storm attempts were made to save as many trees as possible. The fallen ones were righted, the torn stumps were cut off and covered, and those trees which had suffered material injuries to their bark, were covered with cloth to keep out insects and fungi as far as possible. The weeks succeeding the storm were warm, and an abundant amount of rain fell. For some weeks in June the trees appeared dormant, then gradually, on such twigs of *that* year as were left, the axillary buds for the year 1897 began to unfold, and produced new leaves, a process much akin to that known as "Johannisgrowth." By September, a growth of six inches or more had been made from those buds. But by far the majority of the trees had no such buds to fall back upon, as all small branches had been torn away. In these trees, numerous adventitious buds broke out from all parts of the trunk and remaining larger branches. In the maples these grew less vigorously than in the elms or sycamores, but in all a round mass of foliage grew during the summer. As the injuries to many of the trees had been very great, this growth was very small and such trees failed to revive this spring (1897). This was true of all the lindens (*Tilia Americana*).

On the morning following the storm some notes and draw ings were made of various twigs, which were marked, with a view to adding something to the discussion of the question whether a tree can form more than one ring of wood in a year under unusual circumstances. The trees noted had lost all their leaves, and in every one new leaves were formed from the buds on the twigs of that year. In the spring of 1897, all the trees which had survived the winter, continued to grow normally from the buds formed on the adventitious shoots. Numerous sections of branches were made early in May to determine the character of the wood formed by the trees during the previous summer. Such sections were made again in the fall (1897) of wood taken from trees which had died during the summer, as well as from living trees.

The contention that more than one ring of wood may be formed in one year is one of long standing, and much has been written both for and against it. Cotta* found that where trees had been injured by insects or frost, such trees made little or no growth subsequent to the injury, and where they did, the new wood did not differ from that previously formed. On the other hand, a very dry period following a spring very favorable to rapid growth, caused a stoppage in the activity of the cambium, which then formed fall wood. A good rain started new activity, spring wood resulted, and thus two rings were visible. Sometimes the two rings could be seen on one side only. Unger,† in a discussion as to whether the development of several generations of buds in any way influences the growth of annual rings, concludes that there is no causal relation, both being due to changing conditions of temperature and moisture. He found but one or two species where there were any signs of double rings. A full discussion of the earlier views is presented by Kny.‡ He had occasion to study this problem near Berlin on some trees defoliated by caterpillars. In several trees of *Tilia parviflora* the leaves were destroyed early in the year, and in July the buds formed for the following year developed. Kny was able to determine positively the presence of two distinct rings of wood as a result of premature development of these

* Cotta, H. Naturbeobachtungen über die Bewegung u. Funktion des Saftes etc. 75. Weimar 1806.

† Unger, F. Über den Grund der Bildung der Jahreslagen dicotyler Holzpflanzen. Bot. Ztg. **5**: 265. 1847.

‡ Kny, L. Über die Verdoppelung des Jahresringes. Verhandl. d. Bot. Ver. d. Prov. Brandenburg **21**: 185. *pl. 1.* 1879.

buds. He determined furthermore that the presence of two rings was evident for several years back, and gradually became obliterated, varying in different branches. The phenomenon was a variable one in other respects, for the two rings did not always occur even in branches from which all the leaves had been removed. He proved the presence of two rings in *Sorbus aucuparia* and *Quercus pedunculata*. *Fagus silvatica* var. *pendula*, which had lost all its leaves, and where a second growth took place, did not form a second ring. Kny suggests at the end of his account, that to prove the relationship between defoliation and wood formation a number of trees ought to be entirely defoliated, and the resulting changes studied.

Acting upon this suggestion, Wilhelm* removed the leaves from some trees of *Quercus sessiliflora* on June 7, and from several others on July 9. Incisions were made in the trunks to study the wood formation. The same was done for a series of control trees of similar age and thickness. In the fall the trees were cut down and examined. A double ring was found, but only on the side of the tree on which the incisions had been made, both in the defoliated and control trees. The youngest ring was characterized by lesser width, and a sudden decrease in the size of the vessels in the center of the ring. The differences were not great enough to warrant the conclusion that a distinct double ring had been formed. He concludes by saying: "The appearance is accordingly a result of injury to the woody cylinder, and is much furthered by defoliation." He found the abnormal growth of wood in the trunk, but no sign of it in the branches, an observation directly opposed to that of Kny. Those trees defoliated in July showed no interruption in the woody ring, although all had produced a second growth of leaves.

The formation of double rings of wood in *Pinus* sp., owing to late spring frosts, has been shown by Hartig† and others. Hartig found branches which had been frozen repeatedly for

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* Wilhelm, K. Die Verdoppelung des Jahresringes. Ber. d. d. bot. Gesell. 1: 216. 1883.

† Hartig, R. Doppelringe in Folge van Spätfrost. Forstlich naturwiss. Zeitschrift 4: 1. 1895.

a number of years; in one instance a branch fifteen years old had no less than ten double rings. An icemantle is formed between the bark and new wood, crushing the latter. When this thaws it remains in its crushed condition and a break is thus formed which is partially filled by the expanding cells of the medullary rays, and by parenchymatous cells, developed from the cambium. Ultimately normal tracheids are formed. In the course of time the masses of wood are separated by a fine brown line. It will be noted that this manner of separating wood rings has nothing in common with that seen in normal wood, where there is a distinct formation of different kinds of cells in the fall and the spring.

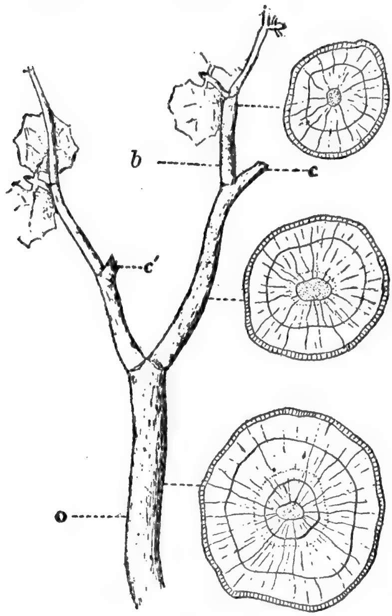

FIG. 1.

On examining the trees in the storm district on May 28, very few trees were found which had twigs of that year, for in the majority of trees, these twigs had been torn away. Thus it came that the observations had to be restricted to the silver maples and sycamores. Fig. 1 is from a sketch of a sycamore twig made after the storm, to which has been added a sketch of the same twig in the spring of 1897. At *o* is the growth of 1895. It had two lateral buds which developed in April, 1896, into two branches. The storm tore these away leaving but the lowest part of each, with one axillary bud. In June these buds grew out into short branches (*b*) which bore normal buds in the fall. At *c* and *c′* are seen the broken ends of the branches. In April, 1897, the buds of the previous fall grew normally, and in May a short branch was at each axil. A cessation of growth had then existed for about a month from May to June, 1896, and it remained to be seen whether this had caused any marked changes in the wood. It is very unreliable, as Kny has shown, to judge of the age of a twig by its external markings, i. e., leaf and bud scale scars, branching, etc., and in determining the age only a personal knowledge of the twig is to be considered. The confusion prevailing on the day after the storm prevented the drawing of many twigs, hence the results are not as full as might be desired. Examinations of numerous twigs this spring (1897) showed appearances similar to those in the twig figured and may be considered as confirmatory in many respects.

Sections were made of the twig described, and these are shown diagrammatically in fig. 1, the dotted lines indicating the point at which the section was made. It was very evident that two rings had been formed during the year 1896. The diagrams of the sections need no explanation. A closer examination of the wood of that year was made. The spring wood of the sycamore consists of very large angular vessels with few wood elements. The latter increase in number toward the fall wood, and at the end of the season's growth are much flattened radially (Pl. V. fig. 1). The wood formed before the storm was normal spring wood. This rather abruptly passed over into wood (Pl. V. fig. 2, b) looking much like normal fall wood. When the twig began its second growth in June a second spring wood appeared (Pl. V. fig. 2, a) which was very distinctly separable from the wood found a month before, thus presenting in all respects the appearance ordinarily seen in normal wood. In fact, the two figures (Pl. V.) are almost identical. On Pl. III. the upper figure represents the cross-section of a sycamore twig taken from an uninjured tree. The inner ring is that formed in 1895, the next one in 1896, the lower figure is from a section of the twig already described. The inner ring is that for 1895; the narrow one following was formed before the storm in 1896; the wood beyond, after the storm. Pl. IV. shows similar conditions existing in a twig of a soft maple. In the latter the double ring was in all respects similar to that found in the sycamore.

The various twigs were studied with a view to determine how far back the abnormal ring could be traced. In the sycamore noted, undoubted traces were found going back for several years, but there was no evidence of the same in the larger branches. The wood taken from the trunks of some thirty maples and sycamores, examined this fall, failed to show any sign of a double ring. These observations agree closely with those made by Kny, who found the double rings in the branches but not in the trunk. If leaf activity and cambial activity stand in any causal relation, it would appear that this is more marked in the younger internodes, where a sudden stoppage in the supply of assimilatory products would be more directly felt than in the trunk. When the leaves stop their activity suddenly, growth in the younger internodes gradually comes to a standstill, to be resumed with renewed leaf activity. It has often been noted, that in those cases, where axillary buds for some reason develop into branches in the same year in which the branch itself develops upon which they are situated, the wood of the parent branch shows no differentiation, probably because the growth was is no way interrupted. From the observations made on the trees of the storm district, it would appear, that interrupted leaf activity on a branch is felt in the younger internodes, causing the formation of an apparent fall wood, which is followed by spring wood when new leaves are formed on that branch, thus giving rise to a double ring. The distance back where this cessation may make itself felt is very variable, depending much upon the position of a branch upon a tree and upon the number of leaves borne by such a branch.

The study of the wood of the trunk had to be necessarily rather conjectural, for there were absolutely no means of determining positively to what year a certain ring belonged. Under conditions of unfavorable nutrition or stunting, trees such as pines, spruces, etc., form no ring whatever.* With the trees of the storm district the conditions surely were unfavorable enough to warrant the assumption of an entire cessation of growth in the months succeeding the storm. With this fact in mind, it is evident, that the last ring formed

* Hartig, R. Zur Lehre vom Dickenwachsthum der Waldbäume. Botanische Ztg. **28**: 508. 1870.

might be either that belonging to 1896 or 1897, and where the outer ring was of peculiar structure, following a normal ring, it was, as a rule, considered as being that formed after the storm in 1896.

The wood of the trunk was affected by the loss of leaves and branches in a manner which was to have been expected. A very much decreased rate of growth was very evident in most cases, irrespective of the species. Some wood had been formed before the storm and in many trees it seemed as if this had been the last, for the outermost ring was very narrow and followed a ring of the usual average width. In other trees two narrow rings were found, outside a wider one, each, perhaps, one-tenth to one-twentieth the width of the foregoing. An excellent opportunity was given for an examination of the wood of the trunk, as most of the injured trees had died during the past summer and were removed this fall. In certain trees, such as the elms, where the rings were not so markedly narrower, the cells of the fall wood were almost parenchymatous.

With the loss of the leaves the entire physiological activity of the tree was deranged. A powerful effort was made by the tree immediately after the storm to produce new leaves, to enable it to carry on the necessary activities. With the loss of the leaves the transpiration current gradually lessened and finally stopped; the flow of assimilatory compounds ceased and to all intents the plant stopped growing. The root system was practically uninjured, and, in the warm weather of the weeks succeeding the storm, in a ground abundantly supplied with water, the activity of the roots must have been a very great one. The rainfall for these months was as follows: May, 9.12 in., June, 4.57 in., July, 4.67 in., August, 2.12 in.,— as against a normal rainfall of: May, 4.58 in., June, 5.08 in., July, 3.76 in., August, 3.50 in. The average mean temperature was, June, 74° F., July, 78.9° F., August 79.4° F., with an average maximum temperature of: June, 82.6° F., July, 87.6° F., August, 88.7° F. These data show conditions very favorable to great root activity. Great volumes of water must have been driven into the trunk, more particularly into the new wood. This stimulated the growth of adventitious buds, which appeared at all points on the trunk and branches. But, with an entire absence of transpiration (or almost so, for the evaporation from the branches and trunk must have been very slight in an atmosphere with high humidity) — this high root activity must soon have stopped, owing to the pressure of the water already absorbed. When the new buds developed into leaves, the number of such leaves formed was entirely incomparable to the number which had been on the tree before, and consequently the surface from which evaporation might have taken place was correspondingly small. This would set up, at best, but a very feeble current, which could in no way balance the volume of water absorbed by an uninjured root system. Under such conditions, a high turgor might be expected to have existed in the new wood and cambium cells in the trunk and branches. After the storm the available supply of assimilatory products could not have been very great, and with little material and a high internal tension, it would seem that cells of unusual form, if not unusual size also, might have been formed by the cambium. In other words the conditions seemed favorable for the development of an oedematous wood. That such did actually happen was plainly evident in a number of trees. These were such as were deprived of most of their branches, and on which but few buds developed. A large maple tree in the eastern part of Lafayette Park may serve as an example. This tree died during the summer of 1896 presumably, for it failed to grow any in 1897 and was cut down in June, 1897. The normal wood of the maple consists of wood fibers of small lumen, arranged in exact radial rows, with an occasional large vessel. (Pl. VI. fig. 1.) The fall wood is marked by several rows of cells, flattened radially. In this maple the outer ring to the unaided eye looked watery and very pulpy. A portion of the bark had been removed from the eastern side by flying missiles during the storm. In June a small crown of leaves was formed but it was evident in September that there was little hope of saving the tree. Examined microscopically this pulpy outer ring appeared like the fig. 2, Pl. VI., which shows the inner part of this ring together with the fall wood of the preceding year. The appearances might be explained as follows.

In April, 1896, the normal radial rows of cells were formed until May 27th. They were thin walled and full of sap. After the storm the cambium continued to form cells, but now under the conditions above described. The new cells, highly turgescent, pressed on the cells already formed, and flattened them in many cases (fig. 2, b), into disc-shaped cells. As the cambium cells continued in their growth, with abundant water passing into the new wood, the resulting cells were very much enlarged and much distorted, bearing in no way any resemblance to normal wood. Numerous large spaces or rifts were formed, probably owing to unequal pressure (Pl. VI. fig. 2, r). This oedematous wood was formed all around the trunk, and was alike at all points, with a possible variation in thickness on different sides.

Among the many maples examined there were but few which showed this condition as markedly as this one. This was a disappointment, as it was hoped that the death of so many trees might in some way be connected with this oedematous wood. Its absence in many trees may be ascribed to their greater vigor, and lesser interruption in the transpiration current. The only other trees with marked oedematous wood were several willows, and in every one of these the malady was very marked. These willows grew near a pond and were close to each other. Two of them had but a trunk and two forks, the others had more branches. It was a surprise to find these willows succumbing to this trouble, and in so marked a manner. The wood of the willow is soft and is composed of very large vessels found in all parts of the wood ring. On Pl. VII. fig. 1, such wood is shown, that is to say, a small piece of fall wood followed by spring wood. Fig. 2 is a portion of the wood from the outermost ring of one of these willows. The cells are thin-walled, of very irregular shape, and much compressed in places. The large vessels are in all cases divided into several parenchymatous cells, which in no way resemble the normal vessels (fig. 2, l). A comparison of figs. 1 and 2 will make this clear. Unfortunately these oedematous trees all died during the year, so no opportunity was given to see what would have been the character of the wood, after more normal conditions had set in. It is very probable that some trees still standing are thus affected, and in the years to come, when any "cyclone" trees are felled, one ought to look for traces of the oedematous wood.

Many of the injured trees struggled along during the summer of 1896, produced leaves in the spring of 1897, and there seemed to be some chance that they might continue to live. As the summer came on, however, another factor entered into their environment which proved fatal to most of them. The trees had a mass of foliage developed in the spring which looked healthy and normal in every respect. After several months of hot and dry weather the bark began to break off in large sheets both from the trunks and branches, particularly from the soft maples. The accompanying plate, (VIII.) reproduced from photographs, shows several maples, an elm and a honey locust from which the bark is breaking away. It will be noted that these trees were not then dead, as most of them had green leaves still on them (figs. 1–4). I attribute this breaking away of the bark to powerful insolation, causing what is known as bark scorching. Hartig* defines the phenomenon of bark scorching (Rindenbrand) as the drying and subsequent dying of the bark of smooth-stemmed trees, which have been suddenly exposed to the sun's rays. He says: "It has been determined that death is a result of intense heating brought about by direct insolation in midsummer." In another place † he discusses the conditions existing in some spruce woods, in which the trees had been defoliated by the nun moth. "On Aug. 19th, the warmest day of 1892, when the thermometer registered at 96.8° F. in the shade and 104.9° F. on a felled area that was not exposed to the wind, it was found that on the southwest side of eighty-year-old spruces, fully exposed to the sun, the temperature was 131° F. between the wood and the bark." The subject of the temperature inside a tree, as compared with that of the air, has been frequently considered. Some observers, such as

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* Hartig, R. Über Sonnenbrand oder die Sonnenrisse der Waldbäume. Unters a. d. forstbot. Inst. z. München. 1880.

† Hartig, R. Diseases of Trees (translated by Somerville & Ward) 294–95. 1894.

Böhm and Breitenlohner,* Becquerel,† Krutzsch,‡ find the internal temperature of a healthy tree normally lower than that of the air, but later researches have shown that, as a rule, the temperature of the layers under the bark is higher by several degrees than the surrounding air. Rameaux § finds that in a poplar branch, 4 cm. in diameter, the internal temperature was 4°, 8°, and 13° C. warmer than the outside air. Ihne ‖ finds the maximum air temperature at about 3 P. M. to be always below that of the tree, often many degrees. Vonhausen ** measured the temperature of a large number of beeches under varying conditions and computes the maximum temperature on the W. S. W. side between the bark and wood 120° F. with an air temperature of 91°. He emphasizes the fact that tender cells, like those of the cambium, cannot withstand so high a temperature for a long time. Russell †† says: "The temperature of the tree as a general rule ranged higher than the outside." When the leaves were removed from a tree of *Abies balsamea* the temperature between the wood and bark was 4–5° higher than in an uninjured tree. Rameaux records a similar increase in temperature in trees whose branches had been removed, amounting to 8–10° C. Hartig explains this increase by "the fact that the trees had small crowns, and that little water found its way into the younger wood rings." ‡‡ The trees in which for some reason the transpiration current had been stopped or much reduced

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* Böhm u. Breitenlohner, Die Baumtemperatur in ihrer Abhängigkeit von äusseren Einflüssen. Wiener Akad. Sitzber. d. math. nat. Classe **75**: 615. I. Abth.

† Becquerel, Compt. Rendus etc. **47**: 717. 1858; **48**: 764. 1859.

‡ Krutzsch, H. Untersuchungen über die Temperatur der Bäume etc. Kön. Säch. Akad. f. Forst u. Landwirte zu Tharand **10**. 1854.

§ Rameaux, M. Des temperatures végétales. Ann. d. Sci. nat., Bot. **19**: 1. 1843.

‖ Ihne, Egan. Über Baumtemperatur unter der Einfluss der Insolation. Allg. Forst u. Jagdzeit. (Supplement) **12**. Heft 4.

** Vonhausen, W. Untersuchung über den Rindenbrand der Bäume. Allgem. Forst u Jagdzeit. **49**: 8. 1873.

†† Russell, H. L. Observations on the temperature of trees. Bot. Gazette **14**: 216. 1889.— See also Hess, Über den Rindenbrand. Forstschutz 541–49. 1878.

‡‡ Hartig, R. Diseases of Trees (tr. by Somerville & Ward) 295. 1894.

always show a marked rise in temperature above that of the atmosphere. Thus the highest is met with in dead trees. In live trees, unless there is a flow of water in the new wood, there is a tendency to equalize the differences in temperature caused by excessive insolation.

In the trees of the storm district the stoppage of this flow of water was felt very soon. During the summer of 1896 the roots continued to send water into the new wood, and the new leaves kept up a feeble current. In the spring of 1897, however, this current was probably very small, for by this time the roots no longer absorbed very much water. The months of June, July, August and September had some unusually hot weather. In June, from the 11th to the 19th, the temperature rose daily above 91° F. (to 96° F. on the 17th); again, from June 29th to July 10th, the same was true. In August, for four days it was 98° F, and from August 26 (101° F) to September 16th, almost three weeks, the average maximum temperature was 95° F. These are temperatures as recorded at the St. Louis Weather Bureau, and in unshaded places, such as Lafayette Park, they were probably some degrees higher. Judging from previous observations, the temperature between wood and bark in the trees of Lafayette Park must have risen to a height sufficient to destroy the delicate cambium cells. With such a small water supply, rapid drying took place, and the bark, breaking away from the woody cylinder, finally peeled off in large pieces. This, as has been said, was true particularly of the maples, which had a smooth bark. Those trees whose trunks had been wrapped with cloth, suffered as much as the unwrapped ones, in many cases more so. The bark peeling took place mainly on the south and southeast sides, though cases of scorching on western exposures were met with. The bark broke away from the branches as well as the trunk, and by the end of September, there was many a tree left standing with no bark whatever on the southwestern side. Under the powerful insolation, rapid drying of the wood occurred, causing longitudinal splitting, which bore much resemblance to frost cracks. Pl. VIII., fig. 3, shows a tree where the wood on the southern side has split in this manner, while the northern section was full of sap. The tree bore a crown of green leaves until the end of September. When this tree was cut down in November, it was found that the whole trunk had become almost dry, except a segment one inch in width on the north side.

As the trees were being cut down in November numerous sections were taken from all parts of trunks and branches to determine the nature and extent of the drying in both wood and bark. The amount of such drying which was found was very large. Of some fifty or more maples the large number when seen in section showed but one-quarter to one-half of the woody cylinder in the normal condition. The drying usually took place in the form of a wedge, which was narrow at first, and gradually increased in width. (See Pl. IX.). Analyses were made to determine the exact amount of water lost. These were made for the soft maple, box elder and linden. The summed-up results are as follows:—

	Number of wood rings.	Per cent. of water.
Acer dasycarpum.		
Wood from north side of trunk.............	outer 4	25.3
Wood from south or scorched side of trunk	outer 5 next 4	12.7 15.5
Negundo aceroides.		
Wood from north side of trunk.............	outer 11 next 8	46.1 28.6
Wood from scorched side of trunk..........	outer 11 next 8	17.7 22.1
Wood from north side of branch............	outer 20	59.0
Wood from scorched side of branch...	outer 20	17.1
Tilia Americana.		
Wood from north side of trunk.............	outer 12	56.6
Wood from scorched side of trunk..........	outer 12	28.2

These analyses were all made in November after the leaves had fallen from the trees. It is doubtful whether any of the trees, from which the wood was taken, would have lived another year. In comparing the results it will be seen that a marked difference existed in all cases between the scorched and healthy sides of the trees. The difference was more marked in the branches than in the trunk, which may be ascribed to their smaller diameter and consequent rapid drying. In those trees where the bark had sustained injuries during the storm, various fungi had found a foothold and their mycelium flourished in the wood of that part, drawing the water to the infected places. This is illustrated by fig. 1, Pl. IX., where the small dark triangle was full of hyphae of a Basidiomycete, and contained very much more water than the adjoining wood. On the opposite side the wood was dry and brittle, falling apart readily. The saw in cutting the limb broke the wood fibers, which accounts for the rough appearance of that half in the photograph. The presence of fungus mycelium was by no means universal. Numerous maples dried very materially without losing their bark, and no fungus could enter on that account. In one tree almost 80 per cent. of the wood was dried and yet the tree showed no sign of this on the outside of the trunk. The leaves on that side were dried, and the whole tree looked sickly. No mycelium could be detected in the wood. Where the fungus threads were present, the limits of the areas in which they were found were usually indicated by dark lines. (See Pl. IX. fig. 2.)

The bark scorching was very universal. Hardly a tree standing in the open was exempt, and, as a result, it may be said that wherever the branches were removed to any extent, especially in the maples, the trees lost their bark this summer. No buds were formed on such trees this fall, and the larger number had to be removed, so that, to-day, of the many beautiful trees, which adorned this section of the city, but a small per cent. still stand, and it seems likely that many of these will not be able to withstand the strain of another summer.

EXPLANATION OF ILLUSTRATIONS.

Plates III.–IX.

Plate III.— *Platanus occidentalis.* Above, transection of twig two years old, × 65. Below, transection of twig injured by the storm, × 75. Both from photomicrographs. *a*, Wood-ring formed in 1895. *b*, Wood-ring formed during April and May, 1896. *c*, Wood-ring formed after May, 1896.

Plate IV.— *Acer dasycarpum.* Above, transection of twig two years old. Below, transection of twig injured by the storm. Both from photomicrographs, × 75. *a*, Wood formed during April and May, 1896. *b*, Wood formed after May, 1896.

Plate V.— *Platanus occidentalis.* Transection of wood. *a*, Wood formed after May, 1896. *b*, Wood formed during April and May, 1896. *f*, Fall wood, 1894. *s*, Spring wood, 1895.

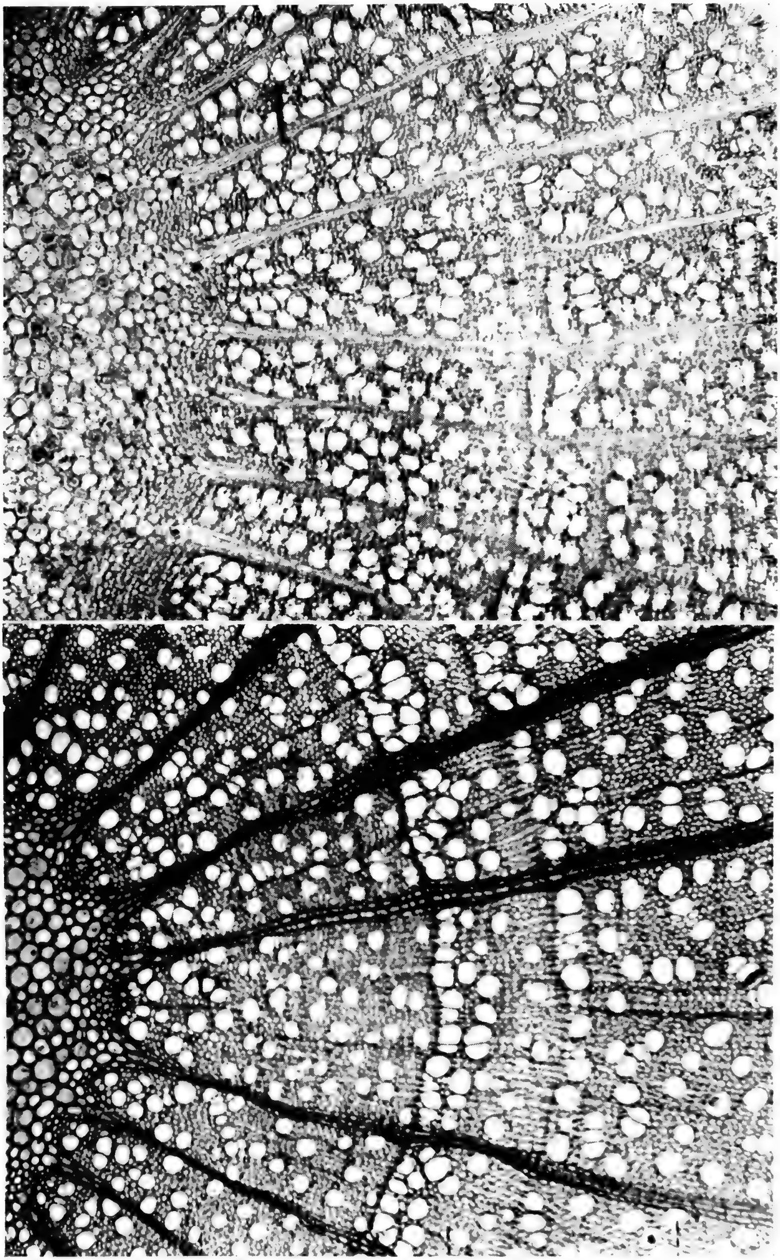
Plate VI.— *Acer dasycarpum.* Transections of wood. 1, Fall wood followed by spring wood. 2, *b*, Wood cells formed in April, 1896, and compressed by the wood outside of it. *f*, Wood formed in the fall of 1895. *o*, Large-lumened cells formed after May 27, 1896. *r*, Break in the tissue.

Pl. VII.— *Salix nigra.* Transections of wood. 1, Healthy wood. *f*, Fall wood. *s*, Spring wood. 2, Oedematous wood. *l*, Division of large vessel.

Pl. VIII.—Trees showing effects of bark scorching. 1, *Robinia Pseudacacia.* 2, 4, 6, *Acer dasycarpum.* 5, *Ulmus Americana.*

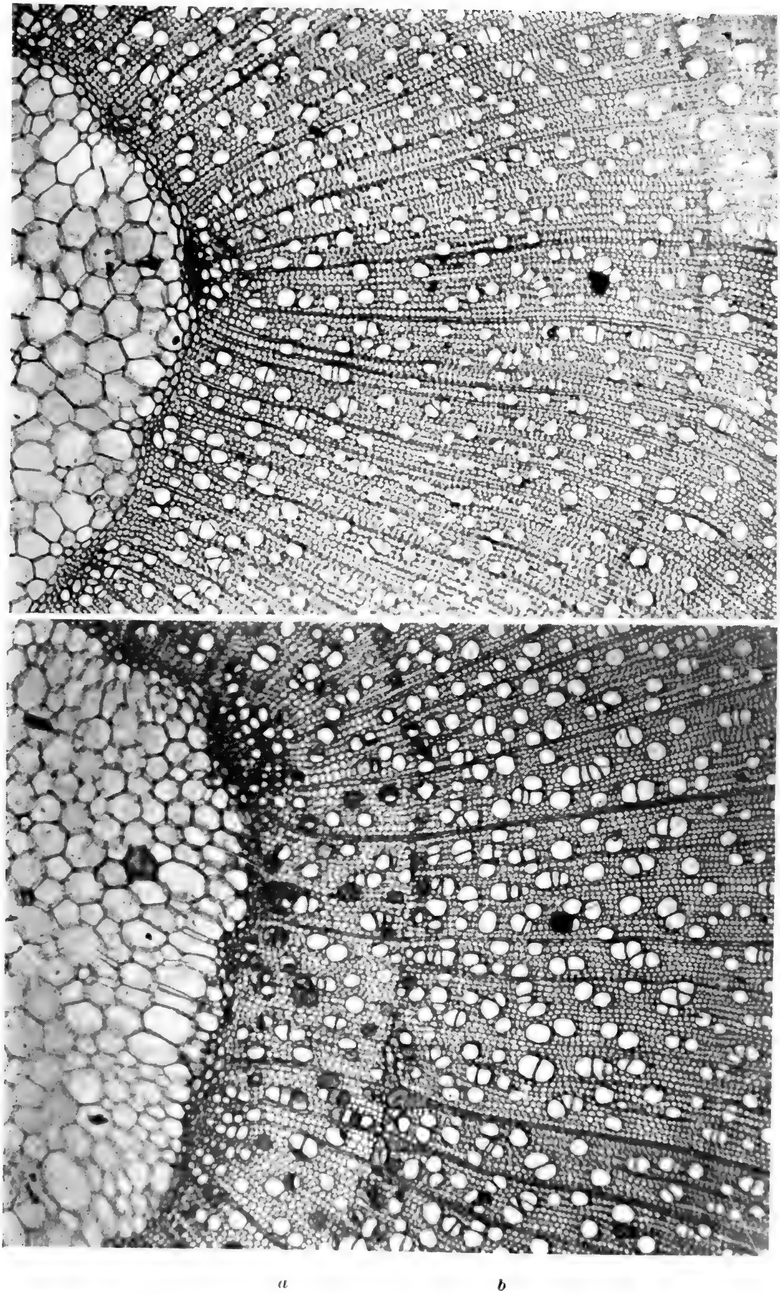
Pl. IX.—1, Transection of linden trunk (*Tilia Americana*) showing drying effects of bark scorching. 2, Transection of maple trunk (*Acer dasycarpum*), showing effects of bark scorching. In the wood between the dark lines numerous fungus hyphae occur.

Issued January 29, 1898.



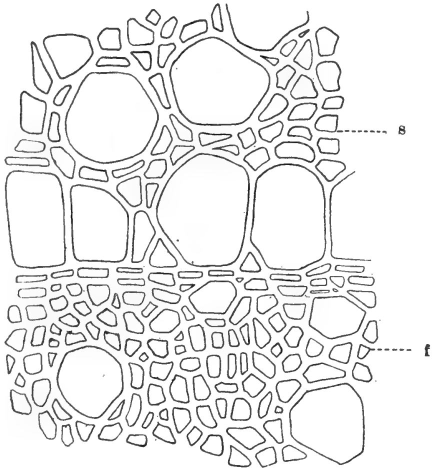
a b c

PLATANUS OCCIDENTALIS.

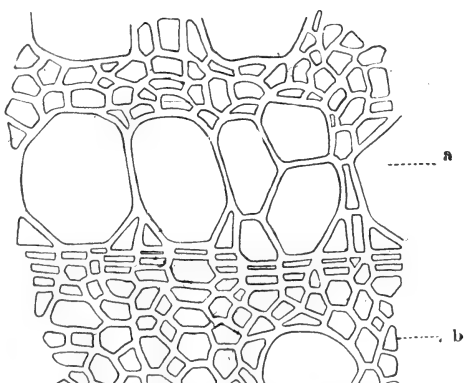


a *b*

ACER DASYCARPUM.

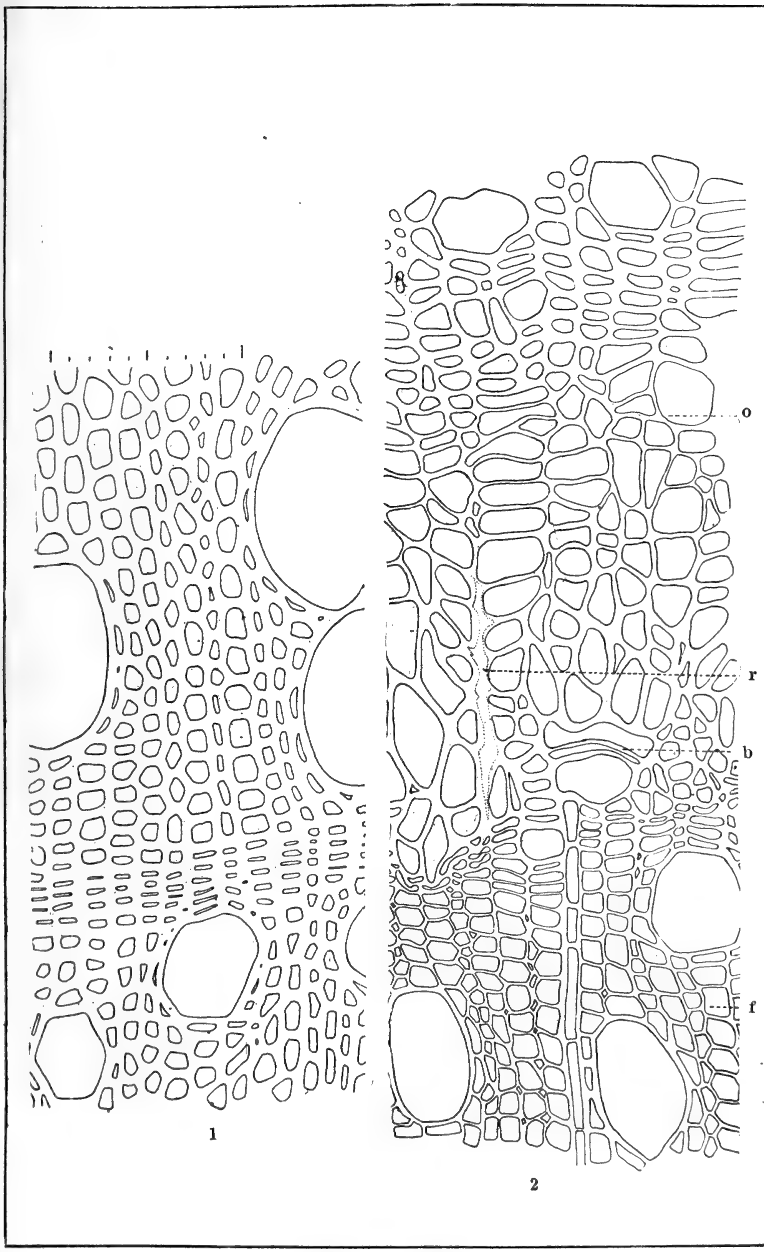


1

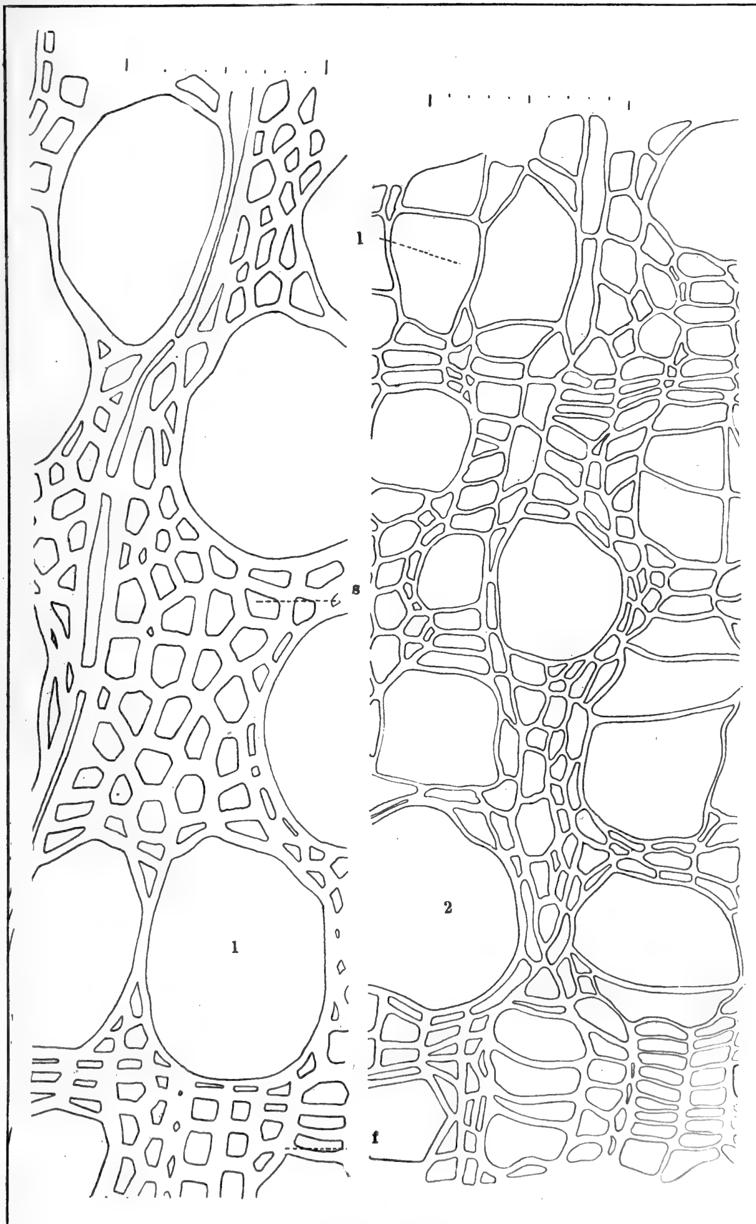


2

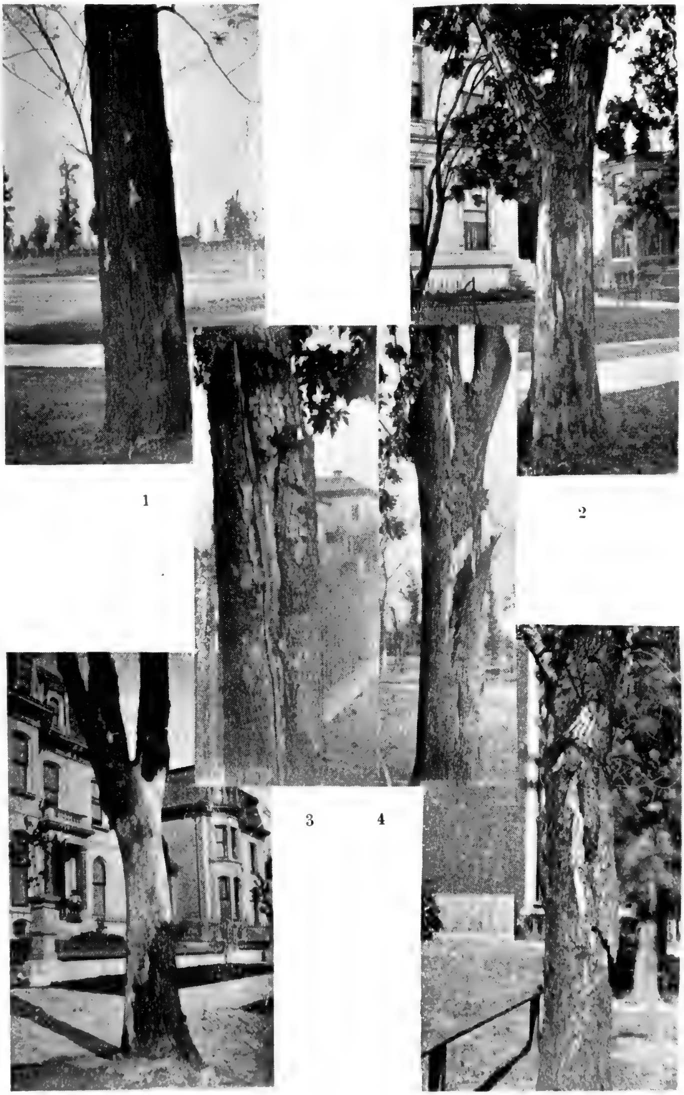
PLATANUS OCCIDENTALIS.



ACER DASYCARPUM.



SALIX NIGRA.



EFFECTS OF BARK SCORCHING.

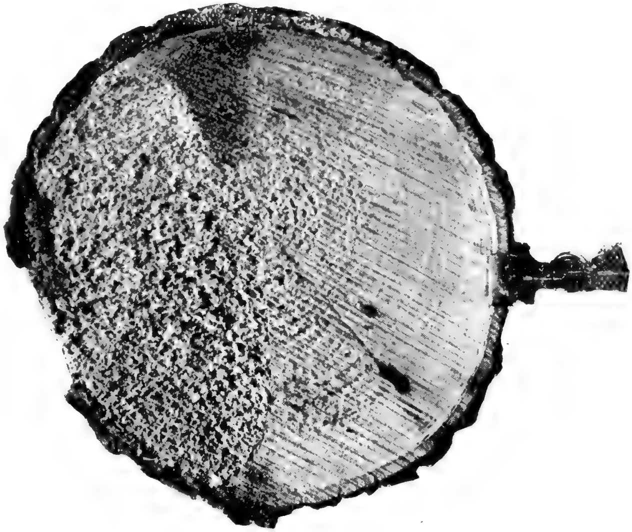


FIG. 1.

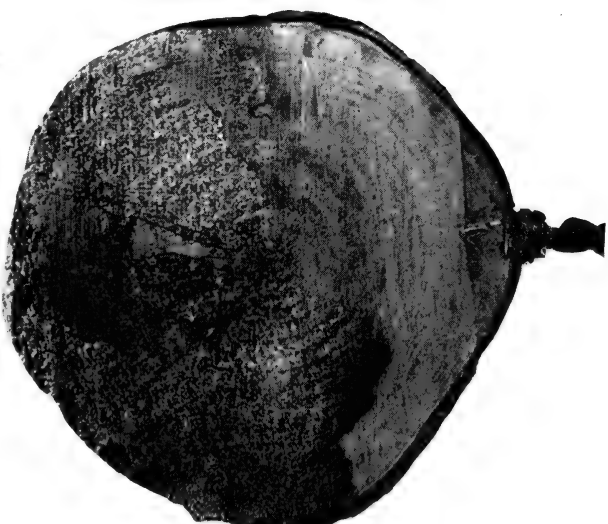


FIG. 2.

EFFECTS OF DRYING ON WOOD.

NEW OR LITTLE KNOWN NORTH AMERICAN BEES.

CHARLES ROBERTSON.*

PROSOPIS THASPII, n. sp.

♀.— Agrees in size with the female of *P. affinis;* head in front appearing more circular than usual, the eyes and vertex more convex; eyes short and broad, meeting bases of mandibles; cheeks short and with the vertex rather strongly produced behind the eyes; head shining and rather sparsely punctured, except in front of ocelli; an impressed line extending forward from anterior ocellus; mesonotum and scutellum finely and rather sparsely punctured; metathorax rather strongly sloping, hardly truncate, inclosure rugose on basal middle; abdomen shining, impunctate; insect black, flagellum beneath, mandibles at tips and tarsi dull ferruginous; a short triangular spot on each side of face, two spots on collar, sometimes wanting, and basal third of hind tibiae, yellow; the other tibiae also show a faint indication of yellow at extreme base; wings subhyaline, nervures, stigma and tegulae dark. Length 6 mm.

Carlinville, Illinois; 2 ♀ specimens, taken June 9th and 14th on flowers of *Thaspium aureum* var. *trifoliatum.*

COLLETES NUDUS, n. sp.

♀. — Black, shining, pubescence thin, pale, except on vertex and thorax above, where it is blackish; face punctured densely below, more sparsely and coarsely above, sides of vertex shining, somewhat doubly punctured; clypeus coarsely striate punctate, apex emarginate; labrum with five more or less evident pits; mandibles, except base, rufo-piceus, space between base and the eye narrow; antennae black or nearly so; prothorax with evident sharp spines; mesonotum punctured closely in front, more coarsely and sparsely on disc, like the scutellum; post-scutellum with a transverse series of sub-

* Presented in abstract to The Academy of Science of St. Louis, January 17, 1898.

quadate shining pits, posteriorly densely punctured; metathorax with usual transverse series of pits, truncation with lateral faces bordered by salient rim; anterior coxae with short, stout spines; wings subhyaline, second submarginal cell longer than third, tegulae and nervures dark; abdomen somewhat shining, sparsely and rather feebly punctured, except towards apex; segments somewhat depressed at base and apex, base of second and apical margins of segments 1–5 with thin fasciae of whitish pubescence. Length 10–12 mm.

♂.— Antennae long, fourth joint as long as second and third together; pubescence on face, cheeks and front femora rather long and dense; space between eye and base of mandible hardly wider than in female; legs slender, abdomen a little more shining. Length 9–10 mm.

Carlinville, Illinois; 3 ♀, 2 ♂ specimens. Of the species known to me this is the most bare. Of those with black hairs on mesonotum the male has the most evident prothoracic spines and the shortest space between eye and mandible, the female has more evident coxae and prothoracic spines than any except *C. armatus* Pttn.

HALICTUS PECTORALIS Sm.

Halictus pectoralis Smith, Brit. Mus. Cat. Hym. **1**: 68. ♀. 1853.

♂.— Closely resembles the female; clypeus without pale markings; the joints of the antennae, except the scape, of about equal length, making the antennae quite short. Length 5–6 mm.

Carlinville, Illinois; Inverness and Orlando, Florida; 50 ♀, 12 ♂ specimens.

In the female the second and third segments of abdomen have a patch of whitish pubescence on each side of base. This species varies with the punctures quite fine and sparse and the inclosure of metathorax poorly defined.

HALICTUS LEROUXII Lep.

Halictus Lerouxii Lepeletier, Hist. Ins. Hym. **2**: 272. ♀. 1841.
Halictus parallelus Smith, Brit. Mus. Cat. Hym. **1**: 72. 1853.
Halictus parallelus Packard, Am. Nat. **1**: 602. 1868.

♂.— Resembles the female; black, clypeus anteriorly, labrum, middle of mandibles sometimes, knees, tibiae except spot in front and behind, and tarsi yellow; ventral segments 4 and 5 short, emarginate. Length 9–12 mm.

Carlinville, Illinois; 34 ♀, 38 ♂ specimens.

The male is larger than that of *H. ligatus* Say and smaller than that of *H. parallelus* Say (= H. occidentalis Cr.) and may be distinguished from both by its darker antennae and mandibles.

HALICTUS LUSTRANS Ckll.

Panurgus lustrans Cockerell, Trans. Am. Ent. Soc. **24**: 147. ♀. June, 1897.

Halictus lustrans Robertson, Ent. News **8**: 172. Sept. 1897.

Hemihalictus lustrans Cockerell, Can. Ent. **29**: 288. Dec. 1897.

I have a specimen from Cockerell. This and *H. anomalus* have only two submarginal cells. They are each more closely related to certain groups of *Halictus* than those groups are to each other.

SPHECODES MINOR, n. sp.

♀.— Black, the abdomen red; head closely punctured, more sparsely on clypeus and on each side of ocelli; mandibles bidentate, rufo-piceus at apex; antennae dull testaceous at apex beneath, joints of flagellum about as long as wide; mesonotum smooth and shining, sparsely and rather coarsely punctured, a fine median line slightly impressed, or even raised anteriorly; scutellum sparsely punctured; metathorax truncate, coarsely reticulated; wings somewhat clouded beyond middle, nervures, stigma and tegulae dark, second submarginal cell narrowing above; abdomen shining, almost impunctate, entirely red. Length 8–10 mm.

Carlinville, Illinois; 10 ♀ specimens.

This species runs smaller than *S. dichrous* Sm. (= *S. arvensis* Pttn.), though some examples of the latter are no larger, and a little larger than *S. confertus* Say (= *S. falcifer* Pttn.). It differs from *S. dichrous* in having the punctuation of the head and thorax finer, though of the same style, the metathorax more rugose, the abdomen brighter red, without black apex and without the strong punctuation.

ANDRENA ILLINOENSIS Rob. form BICOLOR, n. f.

Two female specimens agree with the normal form in all respects except that the abdomen is reddish, except two black spots on second segment indicating the position of the usual foveae.

ANDRENA MARIAE Rob. form CONCOLOR, n. f.

This species was based on examples with the abdomen red. I separate as a form the specimens which are entirely black. The abdomen is usually all red or entirely black, only rarely black with a trace of red. All of the males I have seen have the abdomen black, or sometimes with more or less red.

ANDRENA FORBESII Rob.

Andrena forbesii Robertson, Trans. Am. Ent. Soc. **18**: 59. ♀. 1891.

♂.— Closely resembles the male of *A. rugosa* Rob., but has the abdomen more closely and strongly punctured, the margins less widely depressed, and the antennae more smooth and shining. Length 8–9 mm.

ANDRENA QUINTILIS, n. sp.

♀.— Resembles *A. forbesii;* the head, except the clypeus, more coarsely and less closely punctured, the pubescence thinner, shorter and paler; thorax above more coarsely and sparsely punctured, pubescence densely plumous, but short and thin, except about shoulders; metathorax coarsely reticulated, the inclosure less distinct; abdomen more strongly and much more densely punctured, except the base of first segment, which is more shining and less closely punctured; fasciae more dense and whiter, interrupted on second segment. Length 10–11 mm.

Carlinville, Illinois, 4 ♀ specimens, taken July 19th, 26th and 29th, on flowers of *Pycnanthemum linifolium* Ph. Of forty-two species occurring in my neighborhood, this is the only one flying at that time.

Of the species of *Andrena* known to me this has the abdomen most densely punctured. The scutellum and post-scutellum resemble those of *A. nuda;* the pubescence also like that of *A. nuda*, but more abundant on mesonotum.

PARANDRENA ANDRENOIDES (Cr.) Rob. form BICOLOR, n. f.

All males I have seen are black. I assume the black female to be normal and propose the form name for the female with red abdomen. Intermediate forms are rather rare.

Of the four species, *Andrena erythrogastra* Ashm., *A. illinoensis* Rob., *A. mariae* Rob. and *Parandrena andrenoides*, the first is the only one in which the abdomen of the female is not commonly, or usually, entirely black. *A. erythrogastra* and *A. mariae* are the only ones in which the males show even a trace of red. A specimen of *A. sphecodina* received from Prof. Cockerell is the only male I have seen with the abdomen quite red. This is probably a synonym of *A. mariae*. By itself the red color is of no value except as indicating a mere variant form.

In Trans. Am. Ent. Soc. 24: 150, Prof. Cockerell says: "Robertson has suggested that *P. andrenoides* may be a *Scrapter*, but Dalla Torre places *Scrapter* as a synonym of *Macropis*, and certainly *andrenoides* is not a *Macropis*." Nevertheless, *P. andrenoides* may be a *Scrapter* and also a *Macropis* in the sense of Dalla Torre. It only follows that his *Macropis* must be defined to include *Scrapter*, just as his *Podalirius* must be defined to include *Entechnia* and his *Eucera* to include *Emphor*.

In Bull. Soc. Ent. France, 1897, 63, Vachal discusses the characters of *Scrapter* and shows the composite character of *Macropis* D. T. It appears that *Scrapter* differs from *Andrena* only, or mainly, in having but two submarginal cells. He says: "De tout ceci il résulte que le chapitre *Macropis* de M. Dalla Torre doit être remanié et les espèces qu'il contient être réparties an moins en trois genres, et même en quatre, s'il résulte de l'examen des types que les especes australiennes de Smith ne peuvent entrer dans aucun des autres."

Whether *Parandrena* is a section of *Andrena* or the same as *Scrapter* remains to be seen. *P. andrenoides* and *wellesleyana* are quite distinct. The males agree in having the angles of the sixth ventral segment reflexed. *Andrena crataegi*, which is not related, is the only *Andrena* in which I have found a similar structure.

Stelis lateralis Cr.

Stelis lateralis Cresson, Proc. Ent. Soc. Phil. 2: 410. ♀ (?). 1864.

♂.— Typically the abdomen has ten spots which are elongate and indented posteriorly, the first three segments usually showing the rounded lateral portions of these spots. It may become 12–16 spotted by the marks on segments 3–5 breaking into spots.

♀.— The abdomen is 8–14 spotted, in various combinations, the spots on 5th segment wanting or nearly so, and those on 4th small. 8-spotted examples may have four spots on each extreme side, or three on each side and two sub-discal on the 4th segment.

Carlinville, Illinois: 9 ♀, 8 ♂ specimens.

I think the type specimen is a male.

Megachile exilis Cr.

Megachile exilis Cresson, Trans. Am. Ent. Soc. 7: 224. 1879.

This was determined for me by Mr. Cresson. Thirty local males differ from the type by having the anterior tarsi black instead of pale ferruginous.

Calliopsis andreniformis Sm.

Calliopsis andreniformis Smith, Brit. Mus. Cat. Hym. 1: 128. ♀. 1853.

In the Synopsis, 295, Cresson indicates that *C. flavipes* Sm. is the male. To be sure, Dalla Torre retains the latter name, but the American part of his catalogue is not connected with the literature. Several times I have taken the sexes in copula.

Panurginus labrosus Rob.

Calliopsis labrosus Robertson, Trans. Am. Ent. Soc. 22: 123, in part. ♂♀. 1895.

♀.— Black, shining, thinly pubescent; face with shallow punctures of medium size, rather sparse, except above antennae; labrum with median space striate, strongly narrowed to a truncate or rounded apex; third joint of antennae about as long as two following together, middle joints of flagellum testaceous beneath; mandibles rufopiceus; anterior and middle knees and tubercles yellow; prothorax and about tubercles with short ochraceous tomentum; mesonotum shining, sparsely punctured except anteriorly; wings hyaline, or nearly so; second submarginal cell shorter than first, narrowed about one-third towards marginal; nervures and stigma fuscous, tegulae testaceous; legs blackish, scopa white; disc of metathorax short, irregularly striate, posterior face shining and impunctate; abdomen shining, especially the first segment, which is almost impunctate, following segments finely punctured, anal fimbria pale ochraceous. Length 6–7 mm.

♂.— Mesonotum more closely punctured; clypeus, a spot above, sides of face nearly as high as antennae, labrum, mandibles except tips, tubercles, tibiae at base and apex, anterior pair, and sometimes middle and hind pair, in front, and tarsi, yellow; middle joints of antennae pale testaceous beneath; median face of labrum narrowed toward apex and slightly emarginate. Length 6–7 mm.

Carlinville, Illinois; 8 ♀, 5 ♂ specimens. The sexes were taken in copula.

PANURGINUS LABROSIFORMIS, n. sp.

Calliopsis labrosus Robertson, Trans. Am. Ent. Soc. **22**: 123, in part. ♂♀. 1895.

♀.— A little smaller than *P. labrosus*, more closely punctured; mesonotum more coarsely punctured and presenting three impressed lines in front; antennae shorter, third joint not equaling next two together, flagellum more testaceous beneath towards tip; anterior margin of clypeus, labrum, and mandibles often of same color; tubercles dark; nervures paler; posterior face of metathorax shining and impunctate above, evenly punctured below. Length, 6 mm.

♂.— Resembles the female; clypeus, a small spot above, sometimes wanting, narrow spots on each side of face; labrum, mandibles except tips, knees, anterior tibiae in front, tarsi, except apical joints of hind pair, yellow; compared with male of *P. labrosus* smaller, less yellow, antennae shorter, darker, mesonotum more coarsely punctured and with three impressed lines in front, median face of labrum more strongly narrowed anteriorly. Length, 5 mm.

Carlinville, Illinois; 15 ♀, 7 ♂ specimens.

PANURGINUS SOLIDAGINIS Rob.

Calliopsis solidaginis Robertson, Trans. Am. Ent. Soc. **20**: 274, ♀. 1893.

♂.— Closely resembles the male of the preceding, but the median face of labrum is not so strongly narrowed as in that species or *P. labrosus*. Length, 5–6 mm.

Carlinville, Illinois; 11 ♀, 7 ♂ specimens.

PANURGINUS RUGOSUS Rob.

Calliopsis rugosus Robertson, Trans. Am. Ent. Soc. **22**: 121. ♀♂. 1895.
Calliopsis fraterculus Cockerell, Can. Ent. **28**: 159. ♂♀. 1896.
Pseudopanurgus fraterculus Cockerell, Can. Ent. **29**: 290. 1897.

From comparisons with *P. aethiops* Cr. it is evident that Prof. Cockerell was not aware that that species already had three "*fraterculi*" in *P. mexicanus* Cr., *P. scaber* Fox and the above. The form of the tubercle at vertex varies in both sexes. I have 14 ♀, 6 ♂ specimens.

Cockerell on Panurgus and Calliopsis, Can. Ent. XXIX., 287–90.— From comparisons with European material received from Friese of Innsbruck, the author refers *Calliopsis compositarum* and *rudbeckiae* to *Panurginus*. I accept this and refer *C. asteris* and *parvus* to the same genus, as also the other species indicated above. The reference of *Panurgus marginatus* to *Halictoides* is probably correct and *P. novaeangliae* goes with it.

Prof. Cockerell's treatment of these genera is likely to create an erroneous impression. In Trans. Am. Ent. Soc. **24**: 150, he says: "It is perfectly evident that the so-called species of *Panurgus* of North America are not all of the same genus," and, in place cited above, "The result is extremely interesting, and seems to show that we have for many years been placing bees in genera to which they by no means belong." To those acquainted with the literature and the bees in question this has been clearly understood, at least since it was distinctly stated by Cresson ten years ago. In the Synopsis, 134, Cresson says: "The genera *Panurgus*, *Calliopsis* and *Perdita*, have been made the receptacle for a number of species which do not properly belong to either of those genera, and have been placed there provisionally until more abundant material can be obtained, when a more careful study may be made of their characters."

NOMADA RUBICUNDA Oliv.

Nomada rubicunda Olivier, Enc. Méth. Ins. **8**: 365. 1811.
Nomada rubicunda Cresson, Proc. Ent. Soc. Phil. **2**: 299. 1863.
Nomada torrida Smith, Brit. Mus. Cat. Hym. **2**: 250. ♀. 1854.

I have a female specimen taken at Orlando, Florida.

NOMADA OBLITERATA Cr.

Nomada obliterata Cresson, Proc. Ent. Soc. Phil. **2**: 301. ♀. 1863.
Nomada bisignata var. *obliterata* Cresson, Trans. Am. Ent. Soc. **7**: 1879.
Nomada bisignata var. *obliterata* Cresson, Synopsis 297. 1887.
Nomada viburni Robertson, Trans. Acad. Sci. St. Louis **7**: 341. ♂. 1897.

This is a good species. I did not capture the female until after I had described the male. I have 2 ♀ and 6 ♂ specimens all agreeing with the type specimen in having the first two submarginal cells united, except one which has two submarginal cells in one wing and three in the other. One female agrees with the description of the type. The other has more yellow on face and metathorax, a line on each side of mesonotum over the tegulae, two spots on pleura and line on postscutellum yellow. Length ♂, 7–9 mm.; ♀, 8–10 mm.

NOMADA ARTICULATA Sm.

Nomada articulata Smith, Brit. Mus. Cat. Hym. **2**: 248. ♂. 1854.
Nomada articulata Robertson, Trans. Am. Ent. Soc. **22**: 124. 1895.

♀.— Very closely resembles the female of *N. cressonii* Rob. The third joint of antennae nearly equals the fourth, mesonotum with less evident appressed pubescence, scutellum more densely punctured and more crested, transverse yellow spot on fifth segment finely roughened and hardly shining, whereas in *N. cressonii* it is shining and sparsely and rather coarsely punctured.

Carlinville, Illinois, 3 ♀, 16 ♂ specimens.

NOMADA BISIGNATA Say.

Nomada bisignata Say, Long's 2nd Exp. **2**: 354. ♀. 1824; Bost. Journ. **1**: 402. ♂. 1853.

This species cannot be identified. I can produce examples of three species which show all of the characters indicated in Say's description.

EPEOLUS LUNATUS Say form CONCOLOR, n. f.

Epeolus lunatus Say. Robertson, Trans. Acad. Sci. St. Louis **7**: 342.

The form name is proposed for the variety (?) having the antennae, labrum, mandibles and legs dark.

EPEOLUS HELIANTHI Rob.

Epeolus helianthi Robertson, Trans. Acad. Sci. St. Louis **7**: 344. ♀. 1897.

♂.— Agrees so closely with female that it does not require separate description.

EPEOLUS BIFASCIATUS Cr.

Epeolus bifasciatus Cresson, Proc. Ent. Soc. Phil. **3**: 38. ♂. 1864.

♀.— Does not require description because of close resemblance to male.

Carlinville, Illinois; 14 ♀, 37 ♂ specimens.

There is a large tubercle on each side of front.

EPEOLUS PUSILLUS Cr.

Epeolus pusillus Cresson, Proc. Ent. Soc. Phil. **2**: 398. ♀. 1864.
Epeolus pusillus Fox, Ent. News **3**: 29. ♂. 1892.
? *Epeolus mercatus* Fabricius, Syst. Piez. 389. 1804.

This seems to be the best guess for *E. mercatus.* Cresson credits *E. pusillus* to Mass. and N. H., and Fox captured it in New Jersey. Cresson's argument does not hold against *E. pusillus*, for he had evidently forgotten it when he wrote: "This [*E. cressonii* Rob.] is probably the true *mercatus*, although the very short description given by Fabricius will apply quite as well to several other species, not found, however, east of the Mississippi River." † Fox captured *E. compactus* in New Jersey, but this is a little larger, has the legs darker and is probably less abundant.

MELISSODES COMPTOIDES, n. sp.

♀.— Black; head clothed with pale pubescence, except on the vertex where it is long, fulvo-ochraceous and usually mixed with black in front; flagellum testaceous beneath; mandibles rufous in middle, at apex with an orange streak, often reduced or wanting; pubescence of thorax above thick and fulvo-ochraceous, on the sides pale, beneath fuscous or black; legs with pubescence largely black or fuscous, mixed with ochraceous on femora and tibiae above, anterior tarsi fulvous beneath; scopa fulvo-ochraceous, hind metatarsus with black pubescence beneath; base of abdomen with pubes-

† Trans. Am. Ent. Soc. **7**: 88. 1878.

cence like that of thorax above, second segment with narrow basal and median fasciae of pale appressed pubescence, third with a broad basal fascia, fourth with a broad band with a subtriangular notch posteriorly on the disc, pubescence beneath black; wings subhyaline, apical margins clouded, nervures dull ferruginous. Length 12–13 mm.

♂.— Head, thorax and legs without black or fuscous hairs; thorax above, and usually the vertex, fulvo-ochraceous, below paler, but the legs sometimes with pubescence fulvo-ochraceous; clypeus, labrum and base of mandibles yellow; antennae beneath fulvous, third joint hardly longer than second, fourth joint nearly as long as next two together; abdomen with fasciae, resembling those of female, the last three segments with black pubescence, beneath the segments have black or fuscous pubescence, pale laterally; tarsi ferruginous. Length 11–13 mm.

Carlinville, Illinois: 11 ♀; 44 ♂ specimens.

The male suggests *M. compta* on account of the black tip of abdomen.

MELISSODES AMERICANA Lep.

Macrocera americana Lepeletier, Hist. Ins. Hym. **2**: 92. ♂. 1841.
Melissodes dentiventris Robertson, Trans. Acad. Sci. St. Louis, **7**: 353. ♂♀. 1897.

Since I described the female I have found male specimens which agree quite closely with Lepeletier's description of *M. americana*.

MELISSODES CONDIGNA Cr.

Melissodes condigna Cresson, Proc. Acad. Sci. Phil. 1878: 207. ♀.
Melissodes palustris Robertson Am. Nat. **26**: 273. ♂. 1892.

Carlinville, Illinois, 6 ♀, 24 ♂ specimens.

MELISSODES SNOWII Cr.

Melissodes snowii Cresson, Proc. Acad. Nat. Sci. Phil. 1878: 211. ♂.

M. nivea Rob. is probably the same, but the second submarginal cell is more than half the length of first, and sometimes quite equal to it.

MELISSODES ATRIPES Cr.

Melissodes atripes Cresson, Trans. Am. Ent. Soc. 4: 275. ♀. 1872.

♀.— The interrupted pubescent fasciae on third and fourth segments are either white or black, so that the abdomen has two or four white spots or none.

♂.— More like the female than any other male I have seen; base of clypeus labrum and base of mandibles pale yellow; third joint of antennae about half as long as fourth, flagellum fulvous beneath; third segment of abdomen with an oblique white patch on each side. Length 14–16 mm.

Carlinville, Illinois; 5 ♀, 2 ♂ specimens.

Issued March 3, 1898.

ECOLOGICAL PLANT GEOGRAPHY OF KANSAS.*

A. S. HITCHCOCK.

The present paper is but a preliminary study of our plant geography. An attempt is made to outline the classes of plant communities found within our borders, but a presentation of the adaptation peculiar to the several classes has been reserved for a future paper.

The nomenclature is that of Gray's Manual, sixth edition. In giving representative lists the rare and local species have been omitted. Only vascular plants are considered.

The eastern fourth of the State is carboniferous, mainly Upper Coal Measures extending west to Cowley, Chase and Riley Counties. West of this is a rather narrow Permian belt, fifty miles in width, more or less. West of this and along the southern border only are the Red-beds, extending from Sedgwick to Clark County. Two narrow areas, first Dakota and then Benton, occupy the north central portion of the State from Republic, to Rice and Hodgeman Counties. The western portion of the State is Tertiary, occupying something less than half the area of the State. There are smaller areas of some other formations, such as Niobrara and Comanche.

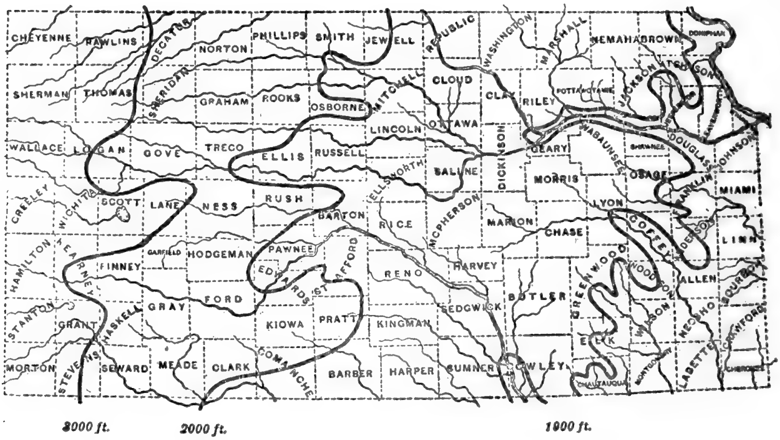
The State is 400 miles in length east and west, by 200 miles in width, north and south. The altitude varies from about 750 feet at the east (in the valleys) to nearly 4,000 feet on the high plains at the west.

The western portion of the State is occupied by the Great Plains. This region extends eastward approximately as far as the western limit of the Permian. The Great Plains is a treeless grassy area, nearly level except as broken by the deep valleys. These valleys cut through the underlying strata, giv-

* Presented to The Academy of Science of St. Louis, February 7, 1898.

ing rocky bluffs, such as the Chalk Bluffs of the Smoky Hill river. In some places the erosion gives rise to canons and buttes. Some of the rivers have a scant supply of timber, which increases as one goes east, but often the valleys are treeless as the Cimarron. The region covered by the Red-beds is characteristically sandy, as is much of the region to the north as far as the Arkansas river.

In the eastern part of the State, the timber along the water-courses increases, and in many places extends over the uplands. The prairie regions are restricted to smaller areas. Limestone hills are a prominent feature of the landscape. In



MAP OF KANSAS.

(Reduced, from 8th Rept. Kansas Bd. Agriculture.)

the southern part are found the Flint hills extending from Chase to Chautauqua County. Salt plains are found in Stafford and Reno Counties.

One of the most important factors in determining the distribution of vegetation is the rain-fall.

The two eastern tiers of counties have above 41 inches. The next tier or so 30 to 40 inches. Three-fourths of the State has usually less than 30 inches, the amount decreasing westward.

There is usually not much snow during the winter, and when it comes it usually remains upon the ground only a short time. The temperature varies between —25° F. and 110° F.

or even more. The minimum temperature is probably 20° higher in southern Kansas than in northern.

In discussing the ecological plant geography, I will follow the classification of Warming, dividing the various communities into four divisions: Hydrophytes, Xerophytes, Halophytes and Mesophytes.

Hydrophytes.

Plants which love the water. They include water plants and swamp plants. There are three groups: A. Plants which are not attached to the substratum and may be submersed or floating. B. Plants attached to the soil but the vegetative portion not extending much above the surface of the water. They include submersed plants and also forms with floating leaves. C. Swamp plants in which the vegetative portion extends into the air.

The hydrophytic vegetation is distributed throughout the State. There is some along every water-course, but the amount found here is comparatively scant. In eastern Kansas bayous and lakes left in old river channels have usually an abundant supply of hydrophytes. Here and there are found isolated swamps in depressions that are not directly connected with a water-course.

Where springs break forth there is usually a swampy area. In western Kansas there are in many places perennial slow-flowing streams of clear water which support a rich hydrophytic vegetation. In some localities, as in Meade and Kiowa counties, large springs break forth into a small river at once. Around these springs one finds besides a rich hydrophyte flora, many species of eastern Kansas. One other habitat for hydrophytes is found in the buffalo wallows. These are depressions found on the high plains, which vary in diameter from a few feet to many rods.

Class I. Floating Plants.

These are found only where there is open water. They float on the surface or at a short distance below.

Of flowering plants there are but a few species. *Utricularia vulgaris*, *Ceratophyllum demersum*, *Spirodela polyrrhiza*, *Lemna perpusilla*, and var. *trinervis*, *Wolffia Columbiana*. *Jussiaea repens* is also often found floating free.

CLASS II. WATER PLANTS ROOTED IN THE SOIL.

This class is represented here and there over the entire State, in ponds, springs, the central part of marshes where there is visible water, and (especially westward) in slow-flowing streams. Some are submersed, when the leaves are finely divided, others have floating leaves, but the vegetative portion does not rise above the surface of the water, except as the water may evaporate and leave the plant in the mud. The flowers are pushed above the surface but the fruit is usually submersed.

Ranunculus divaricatus, *R. multifidus*, *Nelumbo lutea*. The leafy blades of the last are usually raised out of the water, yet the plant should undoubtedly be classed here. *Nymphaea odorata*, *Nuphar advena* (leaf blades frequently emersed), *Nasturtium officinale*, *Myriophyllum spicatum*, *M. scabratum*, *Callitriche heterophylla*, *Jussiaea repens*, *Herpestis rotundifolia* (also a swamp plant), *Elodea Canadensis*, *Heteranthera limosa*, *H. reniformis*, *H. graminea* (these three grow also in the mud), *Potamogeton* (several species), *Ruppia maritima*, *Zannichellia palustris*.

CLASS III. SWAMP PLANTS.

The plants are rooted in the soil, which is saturated with water and may be submersed, but the vegetative organs extend above the water when it is present as a sheet. This class is usually found around the borders of the preceding class and also along rivers and ponds in which the preceding class may be absent. The species are too numerous to give a detailed list. But we may distinguish a few communities which often have many species in common but which possess a distinctive physiognomy.

Reed-Swamps. These occur in swampy depressions or along water-courses. The plants are mostly with upright leaves and are chiefly monocotyledons. During the rainy season (spring and early summer) the swamp may show much open water between the plants, but later the water may entirely dry up leaving the plants to winter in the hard ground. The following would be characteristic: *Typha latifolia*, *Sparganium eurycarpum*, *Alisma Plantago*, *Sagittaria* (several species), *Eleocharis* (several species), *Scirpus lacustris* and other species, *Carex* (several species, as *C. filiformis latifolia*, *C. hystricina*).

Bogs. These are found in the neighborhood of springs and hence are supplied with water the year around. Many of the plants of the preceding sub-class, are found here, but particularly the following: *Cardamine rhomboidea*, *C. parviflora*, *Lythrum alatum*, *Ludwigia alternifolia*, *Epilobium lineare*, *E. coloratum*, *Berula angustifolia*, *Eupatorium perfoliatum*, *Mimulus Jamesii*, *Gerardia tenuifolia*, *Lycopus rubellus*, *L. lucidus Americanus*, *L. sinuatus*, *Juncus* (several species), *Cyperus* (several species, as *C. esculentus*), *Phragmites communis* (local).

Buffalo Wallows. Depressions in the soil found scattered over the plains in western Kansas. During the wet season they hold water but are dry in the latter part of the year. The plants are mostly annuals. *Ammannia Wrightii*, *Oenothera canescens*, *O. triloba parviflora*, *Actinella odorata*, *Lippia cuneifolia*, *Eriochloa polystachya*, *Panicum colonum*, *Eragrostis pilosa*.

Borders of ponds and marshes (more rarely borders of streams). This formation might more properly come among the mesophytes but it will be included here for convenience. It occurs between the swamp formation and the true mesophyte flora. *Lippia lanceolata*, *Leersia oryzoides*, *L. Virginica*.

Sandy or muddy borders of streams. This formation is found on sand-bars or mud-banks in the latter part of summer when the water has subsided. The plants are mostly small annuals. *Conobea multifida*, *Ilysanthes riparia*, *Cyperus aristatus*, *C. diandrus*, *Eragrostis reptans*.

CLASS IV. SHRUB-SWAMPS.

These are found only through the eastern part of the State. There is much open water, and herbaceous vegetation is more or less suppressed by the shrubby growth. In between the patches of shrubs will usually occur reed swamp vegetation. The most common shrub is *Cephalanthus occidentalis.* In southeastern Kansas, the tall herb *Hibiscus militaris* often occurs in the community. *Salix longifolia* may occur in swamps, but forms characteristic communities along river banks, especially portions liable to inundation.

Xerophytes.

As one would suppose from its geographical position, the flora of Kansas is largely xerophytic. The group may be conveniently divided into three classes: A. Rock vegetation. B. Sand vegetation. C. Prairie.

CLASS V. ROCK VEGETATION.

The exposed rock is chiefly limestone. There is some gypsum in western Kansas and sandstone in the Dakota formation, and the Red-beds, also considerable through the region of Chautauqua County and many other localities. However, the composition of the rock seems to have little influence upon the vegetation, other influences being more important in determining the distribution. Ferns are found growing in the crevices of naked rock in some localities in eastern Kansas, as Chautauqua County and "Rock City," Ottawa County: *Notholaena dealbata*, *Pellaea atropurpurea*, *Camptosorus rhizophyllus.* The limestone hills found in abundance through the State have frequently considerable soil scattered over them. The characteristic flora of this formation includes quite a long list. In eastern Kansas are the following: *Petalostemon multiflorus*, *Astragalus lotiflorus*, *Oenothera Missouriensis*, *Stenosiphon virgatus*, *Mentzelia oligosperma*, *Peucedanum foeniculaceum*, *Houstonia angustifolia*, *Amphiachyris dracunculoides*, *Aster oblongifolius rigidulus*, *A. sericeus*, *Echinacea angustifolia*, *Helianthus orgyalis*, *Hymenopappus corymbosus*, *Senecio Balsamitae*, *Heliotropium tenellum*, *Lithospermum angustifolium*, *Pentstemon Cobaea*, *Euphorbia zygophylloides*, *Croton monanthogynus*, *Tragia stylaris*, *Camassia Fraseri*, *Zygadenus Nuttallii*, *Bouteloua hirsuta*.

Most of these have strong woody tap roots which penetrate the clefts in the rock. Two have bulbs (*Camassia*, *Zygadenus*). Four are annuals (*Amphiachyris*, *Heliotropium*, *Euphorbia*, *Croton*), the others perennials or biennials.

Certain shrubs often give a peculiar physiognomy to the hills, especially along the margins of woods which often follow up the ravines. These are *Ceanothus ovatus*, *Rhus glabra*, *R. Canadensis*, *Cornus asperifolia*, *Symphoricarpus vulgaris*. None of these are, however, confined to the hills, but grow freely in open woods or even along the streams. *Juniperus Virginiana* is rarely found except along these limestone hills.

In the western part of the State the species change though the physiognomy remains the same.

Clematis Fremonti (central Kansas only), *Stanleya pinnatifida*, *Lesquerella ovalifolia*, *Psoralea cuspidata*, *Dalea aurea*, *Petalostemon tenuifolius*, *Astragalus Missouriensis*, *Oenothera Fremontii*, *O. Hartwegi*, *Mentzelia ornata*, *Aster Fendleri* (on gypsum hills only), *A. ericaefolius*, *Melampodium cinereum*, *Zinnia grandiflora*, *Riddellia tagetina*, *Actinella scaposa linearis*, *A. acaulis*, *Gilia rigidula acerosa*, *Pentstemon albidus*, *Scutellaria Wrightii*, *Paronychia Jamesii*, *Eriogonum longifolium*, *Euphorbia lata*, *E. Fendleri*, *Yucca angustifolia* (also on barren sandy-clay hills).

All perennials or (*Mentzelia*) biennials. Shrubs are present only in the cañons or ravines, they are *Rhus Canadensis trilobata*, *Prunus Besseyi*.

It will be observed that most of the plants of the rock flora are perennials, that they have reduced leaf surface, narrow as in *Actinella scaposa linearis*, bract-like as in *Paronychia Jamesii*, cut into small divisions as *Peucedanum*, compound with small leaflets as *Dalea;* or if the leaves are not particularly small they are thick and leathery as in *Clematis* and *Pentstemon Cobaea;* or that they are hairy, *Lesquerella ovalifolia* (stellate hairs), *Oenothera Missouriensis* (silky hairs), *Mentzelia* (very rough tuberculate). Plants with running root-stocks are very uncommon.

CLASS VI. SAND-HILL VEGETATION.

Sand-hills are found more or less throughout the State, usually near rivers, and in such cases represent an old river bed at a time when a much greater quantity of water passed through the valley than at present. Frequently these sand-hills have the character of shifting dunes. A well-marked range of sand-hills extends along the Arkansas river on the south side. At Garden City these hills are eight miles across the dunes. At Hartland there are several miles of shifting dunes known as the bald hills. The dunes are probably fifty feet high from base to summit, and entirely devoid of vegetation except around the base. They slope gradually toward the southwest from which direction come the prevailing winds, while on the opposite side the inclination is the greatest possible for loose sand. Only four species of plants were observed on these hills, two binding grasses, *Ammophila longifolia* and *Redfieldia flexuosa*, which extend up the side a short distance, and occasionally *Asclepias arenaria* and *Physalis lanceolata pumila*. The inhabitants of the region informed me that the bald hills are less extensive than formerly.

Sand-hills occur south of the Cimarron river, extensively through Stafford, Reno, and Rice Counties. Much of the soil through Harper, Barber, Kingman and Pratt Counties is sandy, though sand-hills do not occur so frequently. The following is a list of characteristic plants: *Polanisia trachysperma*, *Psoralea lanceolata*, *Desmodium sessilifolium*, *Lespedeza capitata*, *Strophostyles pauciflorus*, *Cassia chamaecrista*, *Liatris squarrosa*, *Heterotheca Lamarckii*, *Chrysopsis villosa*, *Aplopappus divaricatus*, *Gnaphalium polycephalum*, *Helianthus petiolaris*, *Artemisia caudata*, *Lithospermum angustifolium*, *Ipomoea leptophylla*, *Pentstemon grandiflora*, *Monarda punctata*, *Amaranthus Torreyi*, *Froelichia Floridana*, *F. gracilis*, *Cycloloma platyphyllum*, *Euphorbia hexagona*, *Cyperus Schweinitzii*, *C. filiculmis*, *Paspalum setaceum*, *Cenchrus tribuloides*, *Sporobolus asper*, *S. cryptandrus*, *Ammophila longifolia*, *Triodia cuprea*, *Eragrostis tenuis*, *E. pectinacea*, *E. capillaris*.

In the western part of the State some of these disappear and the following become common: *Cleomella angustifolia*, *Talinum calycinum*, *Indigofera leptosepala* (S. W. Kansas), *Gaura villosa*, *Mentzelia multiflora*, *Erigeron divergens*, *Aster tanacetifolius*, *Hymenopappus flavescens*, *Polypteris Hookeriana*, *Gaillardia pulchella*, *G. aristata*, *Artemisia filifolius*, *Gilia aggregata*, *Heliotropium convolvulaceum*, *Krynitzkia Jamesii*, *Asclepias arenaria*, *Physalis lanceolata pumila*, *P. hederaefolia*, *Oxybaphus* sp. (allied to *O. albidus*), *Abronia fragrans*, *Corispermum hyssopifolium*, *Eriogonum annuum*, *Euphorbia Geyeri*, *E. petaloidea*, *Stillingia sylvatica*, *Commelina angustifolia*, *Andropogon Hallii*, *Stipa comata*, *Redfieldia flexuosa*, *Gymnopogon racemosa* (S. Kansas), *Eragrostis oxylepis*.

A large number of the species are not found, within our limits, in any other than sandy soil. Several plants that are characteristic of the plains in west Kansas extend eastward in the sand-hills, such as *Ipomoea leptophylla*. Some plants of the surrounding prairie may extend more or less into the sand-hills, such as *Ambrosia psilostachya*. The cactuses are rarely found in the sand-hills.

A large proportion of the species are annual. The perennial plants frequently have extensively creeping root-stocks, such as the binding grasses mentioned. Others form deep slender roots which appear to reach down to permanent moisture, as *Physalis* and *Asclepias*. *Artemisia* forms a thick crown and helps materially in retarding the shifting sand, as do some of the bunch grasses. *Ipomoea leptophylla* and *Cycloloma* are tumble weeds.

In the eastern sand-hills a shrub, *Prunus angustifolia*, frequently forms quite extensive thickets which tend to bind the sand. *Amorpha canescens* is also frequent. This small shrub is also common on the prairie.

CLASS VII. PRAIRIE.

Prairie is more extensive than all the other formations together. The western half of the State is in the region known as the Great Plains, which extends west to the mountains, south into Texas and far northward. In this region the land is nearly level, broken here and there by valleys of streams. One can often travel many miles on the uplands with no perceptible undulation to break the monotony of the level plain extending to the horizon on all sides. There are no trees, no shrubs (though many of the plants have a lignescent base), no tall herbs. The distribution of *Malvastrum coccineum* shows fairly well the extent of this region. Our collections show the eastern limit of this species to be the following counties: Republic, Cloud, Ottawa, Ellsworth, Rice, Stafford, Pratt, Barber. East of this region there is much prairie on the uplands, but it decreases as one goes eastward, so that in the eastern counties the amount is comparatively small as to total and limited in extent as to individual areas.

The following plants are characteristic of the western plains: *Erysimum asperum*, *Polygala alba*, *Malvastrum coccineum*, *Linum rigidum*, *Sophora tomentosa*, *Psoralea tenuiflora*, *Cereus viridiflorus* (S. W. Kansas), *Opuntia Rafinesquii*, *O. Missouriensis*, *O. fragilis*, *Gutierrezia Euthamiae*, *Aplopappus spinulosus*, *Evax prolifera*, *Engelmannia pinnatifida*, *Thelesperma gracile*, *Artemisia Wrightii*; *Senecio Douglasii*, *Cnicus ochrocentrus*, *Asclepias Jamesii*, *Krynitzkia crassisepala*, *Ipomoea leptophylla*, *Solanum triflorum*, *Chamaesaracha sordida*, *Verbena bipinnatifida*, *Cladothrix lanuginosa*, *Chenopodium olidum*, *C. Fremonti incanum*, *Allium Nuttallii*, *Aristida purpurea*, *Munroa squarrosa*, *Elymus Sitanion*. The following also extend further east: *Kuhnia eupatorioides*, *Liatris punctata*, *Solidago Missouriensis*, *Ambrosia psilostachya*, *Lepachys columnaris*, *Echinospermum Redowskii occidentale*, *Evolvulus argenteus*, *Solanum rostratum*, *Oxybaphus angustifolius*, *Andropogon furcatus*, *Andropogon scoparius*, *Chrysopogon nutans* (these three grasses are predominant in the eastern prairies), *Schedonnardus Texanus*, *Bouteloua oligostachya*, *B. racemosa*, *Buchloe dactyloides*, *Koeleria cristata*, *Eatonia obtusata*.

In the so-called " second bottom " of the valleys are found: *Cleome integrifolia*, *Astragalus mollissimus*, *A. gracilis*, *Cucurbita foetidissima*, *Sporobolus airoides*.

The physiognomy of the western plains is peculiar. The predominant plant is buffalo grass (*Buchloe dactyloides*) with often considerable grama grass (*Bouteloua oligostachya*). This forms a close mat two or three inches high of a grayish-green color. The other plants are scattered here and there in this sod. The *Opuntias* are conspicuous though they creep along edgewise, and rise but little above the grass. The most conspicuous plants are *Asclepias Jamesii* and *Cnicus ochrocentrus*, which are one to two feet high.

Certain of the plants in the list are found chiefly in new ground, such as fire-guards and prairie-dog towns. These are: *Echinospermum*, *Krynitzkia*, *Solanum triflorum*, *S. rostratum*, *Chamaesaracha*, *Verbena*, *Cladothrix*, *Chenopodium Fremonti incanum*, *Schedonnardus*, *Munroa*.

I have spoken previously of the xerophytic character of the plants of the plains (Contr. Nat. Herb. 3: 538). Though the species vary somewhat as one goes west, the physiognomy remains the same and the community cannot be broken up readily into subformations, as is the case with most of the other classes.

In eastern Kansas the species in addition to those mentioned above are: *Anemone decapetala*, *Delphinium azureum*, *Callirrhoe triangulata*, *C. alcaeoides*, *Linum sulcatum*, *Baptisia australis*, *B. leucophaea*, *Psoralea argophylla*, *P. floribunda*, *P. esculenta*, *Petalostemon violaceus*, *P. candidus*, *Astragalus caryocarpus*, *A. Plattensis*, *Desmodium Illinoense*, *Lespedeza capitata*, *Schrankia uncinata*, *Liatris pycnostachya*, *L. scariosa*, *Grindelia squarrosa*, *Solidago rigida*, *Silphium laciniatum* (compass plant), *Helianthus rigidus*, *Coreopsis palmata*, *Cnicus undulatus*, *Asclepiodora viridis*, *Lithospermum angustifolium*, *Salvia azurea grandiflora*, *Panicum scoparium*, *P. depauperatum*, *Stipa spartea*.

Through eastern Kansas occur small areas the vegetation of which probably should be classed with the xerophytes. They are usually referred to as "sterile places." They are open barren spots owing their dryness to the character of the soil. The following plants are frequently found in such localities: *Draba Caroliniana*, *Silene antirrhina*, *Sagina decumbens*, *Hypericum Drummondii*, *Stylosanthes elatior*, *Cuphea viscosissima*, *Diodia teres*, *Androsace occidentalis*, *Hedeoma hispida*, *Plantago Patagonica gnaphalioides*.

The nearest representation which we have of the xerophytic forest flora is the oak scrub, found on dry hills through eastern and southern Kansas. The trees are mostly oaks, *Quercus nigra*, *Q. tinctoria*, *Q. Muhlenbergii* and *Q. prinoides*.

Halophytes.

This sub-division is rather sparsely represented in Kansas, the plants being confined to the salt marshes.

CLASS VIII. SALT MARSH VEGETATION.

These salt marshes are found in Stafford and Reno Counties, and less frequently in some other counties. During the dry season the water disappears and there is a salt plain. In Stafford County the Big Salt Marsh covers several square miles, and during the dry season a large part of it is entirely devoid of vegetation, a level sheet of white. There are certain species found only where the soil is more or less salty, but these species are often mixed in with others in soil that is only slightly salty, not enough to be called a salt marsh or plain. These areas are commonly known as alkali spots. The list of species is comparatively short. *Aster exilis*, *Flaveria angustifolia*, *Chenopodium rubrum*, *Atriplex expansa*, *A. argentea*, *Suaeda diffusa*, *Scirpus maritimus*, *Distichlis maritima*, *Agropyrum glaucum*. All but the last three are annual, these three perennial by creeping rootstocks. *Distichlis* and *Agropyrum* are widely distributed. The former is quite abundant at the foot of gypsum hills where the soil is impregnated with gypsum and magnesium, but is wet during a part of the year.

Mesophytes.

The mesophytic flora is abundant in eastern Kansas, but decreases rapidly westward, where it is confined to the vicinity of the streams.

CLASS IX. MEADOWS.

Under this title is included the grass vegetation lying near the streams, but beyond the hydrophytic formation. The meadows are usually subject to overflow during the wet season and may be quite dry during the dry season. They are commonly known as bottom lands. Also much of what are termed sloughs come under this class, though they may have a hydrophytic formation in the center. Grasses (especially *Spartina cynosuroides*) and sedges predominate, but have a mixture of various perennial herbs scattered through. It is scarcely worth while to give more than a short list of the species which will serve as examples.

In eastern Kansas the bottom land flora would be illustrated by *Desmanthus brachylobus*, *Vernonia Baldwinii*, *Solidago lanceolata*, *Aster paniculatus*, *Erigeron Canadensis*, *Iva ciliata*, *Ambrosia trifida*, *Helianthus grosse-serratus*, *Polygonum incarnatum* and other species, *Carex straminea* and other species, *Spartina cynosuroides*.

CLASS X. FIELDS.

This formation is found on dryer ground than the preceding and in the wooded region would be replaced by forest if this were not prevented by man. In other regions the tendency is to return to prairies. In cultivated fields the plants which intrude are known as weeds. These have already been discussed in the Bulletins of the Kansas Experiment Station (Nos. 50, 52, 57, 66, 76). In fields formed by breaking prairies the weeds should in most cases be classed as mesophytes.

CLASS XI. DECIDUOUS FORESTS.

As previously stated considerable of the area in the eastern part of the State is covered with forests. These forests are best developed in the valleys of the rivers, especially the Missouri, Kansas, Marais des Cygnes, Neosho and Verdigris. The forest extends in many places onto the uplands, but becomes then quite sparse. As one travels west the belt of timber along the streams becomes narrower and the species fewer till it entirely disappears in the western part of the State. It is noticeable that in many parts of the State where the timber may be scattering or absent along the main river, one can find a much better representation at the heads of the draws or cañons in the edges of the valley some distance from the stream.

A full discussion of the distribution of Kansas trees will be found in the eighth Biennial Report of the Kansas State Board of Agriculture.*

I will give here only an outline of communities as so far observed.

Copses. Thickets found along the margins of woods or in the meadows previously described. Also along the banks of water-courses. They consist of *Rhamnus lanceolata*, *Rhus glabra*, *Pyrus coronaria*, *P. Ioensis*, *Prunus Americana*, *Cornus asperifolia*, *Corylus Americana*. Where the soil is moist *Amorpha fruticosa* is common. Climbing vines are common, such as *Celastrus scandens*, *Vitis riparia*, *Polygonum dumetorum scandens*. In the moist thickets along streams, *Apios tuberosa*, *Amphicarpaea monoica*, *Echinocystis lobata* and *Sicyos angulata*, occur. Along fences and similar habitats one finds many of these shrubs and also *Rhus Toxicodendron*, *Rubus occidentalis*, *Rubus villosus* and *Rosa setigera*. With these are found a number of tall herbs such as *Solidago Canadensis*, *S. serotina*, *Erigeron Canadensis*, *Lactuca Canadensis*.

Lowland Woods. In the bottom land along streams which are not subject to overflow except in unusually high water we find the timber reaching its greatest development. The following are characteristic.— Trees: *Asimina triloba*, *Tilia Americana*, *Acer dasycarpum*, *Negundo aceroides*, *Cercis Canadensis*, *Gymnocladus Canadensis*, *Gleditschia triacanthos*, *Ulmus fulva*, *U. Americana*, *Celtis occidentalis*, *Morus rubra*, *Platanus occidentalis*, *Juglans nigra*, *Carya olivaeformis*, *C. sulcata*, *C. amara*, *Quercus macrocarpa*, *Q. palustris*, *Salix amygdaloides*, *S. nigra*, *Populus monilifera*. Shrubs: *Menispermum Canadense*, *Xanthoxylum Americanum*, *Vitis cinerea*, *V. cordifolia*, *Aesculus arguta*, *Staphylea trifolia*, *Ribes gracile*, *Sambucus Canadensis*, *Symphoricarpos vulgaris* (found in several communities), *Smilax hispida*. Herbs: only a very few common ones will

* Mason, A Preliminary Report upon the Variety and Distribution of Kansas Trees, p. 259.

be given: *Ranunculus abortivus, Viola palmata cucullata, V. pubescens, Claytonia Virginica, Geum album, Cryptotaenia Canadensis, Chaerophyllum procumbens, Sanicula Marilandica, Eupatorium purpureum, E. ageratoides, Solidago ulmifolia, Ambrosia trifida, Rudbeckia laciniata, Actinomeris squarrosa, Bidens frondosa, Lactuca Floridana, Campanula Americana, Ellisia Nyctelea, Echinospermum Virginicum, Scrophularia nodosa Marylandica, Polygonum Virginicum, Laportea Canadensis, Pilea pumila, Erythronium albidum, Cinna arundinacea.*

Upland Woods. Extending along the bluffs, hillsides or uplands. Trees: *Acer saccharinum, Fraxinus Americana, Carya alba, Ostrya Virginica, Quercus stellata, Q. Muhlenbergii, Q. coccinea tinctoria, Q. nigra.* Herbs: where the soil is rich with leaf mould, such as moist hillsides near the larger streams in eastern Kansas, one finds, *Isopyrum biternatum, Podophyllum peltatum, Sanguinaria Canadensis, Dicentra Cucullaria, Dentaria laciniata, Osmorrhiza brevistylis, O. longistylis, Asarum Canadense, Polygonatum giganteum, Smilacina stellata, Uvularia grandiflora, Arisaema triphyllum, Uniola latifolia, Poa sylvestris.*

In the dryer and more open woods the following are common: *Agrimonia Eupatoria, Triosteum perfoliatum, Solidago Lindheimeriana, Aster Drummondii, A. paniculatus, Antennaria plantaginifolia, Helianthus hirsutus, Cacalia atriplicifolia, Veronica Virginica, Verbena Aubletia, Phryma leptostachya, Teucrium Canadense, Pycnanthemum linifolium, Monarda fistulosa, Chenopodium Boscianum, Muhlenbergia sylvatica.*

Issued March 8, 1898.

THE MOLLUSCAN FAUNA OF WESTERN NEW YORK.*

FRANK COLLINS BAKER.

The mollusks enumerated in the following pages were collected by the writer while on his vacation from July 5th to July 29th, 1897. During that time about seventy-five species were obtained, represented by over 1,500 specimens. To make the list of more value the writer has incorporated several local lists with his own,† and the paper may be considered, therefore, a pretty complete catalogue of the land and fresh water shells of the western part of the State of New York. Species not found by the writer are marked by an asterisk.

Local lists are seldom accompanied by a list of the exact stations (and also a somewhat detailed description of the same) and the writer believes that the present contribution will be of some value on this account, as great care has been taken in examining and recording every locality.

The western part of New York is an especially good region for animals of this class; there are a large number of streams in which the fresh water forms thrive, and moist woodlands

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* Presented in abstract before The Academy of Science of St. Louis, Oct. 18, 1897.

† The following publications have been consulted and species therein recorded added to the present list: —

Walton, John. The Mollusca of Monroe County, N. Y. Proc. Roch. Acad. Sci. 2: 3–18.

Banks, Nathan. The Land Mollusca of the Cayuga Valley. The Nautilus 5^{12}: 137–9. 1892.

Dewey, Prof. C. List of Naiades (clams), found in Western New York, and sent to the State Collection at Albany, with some chiefly from Ohio. Ninth Annual Report of the Regents of the University of the State of New York, 1856, pp. 31–38.

These are all the papers relating to the Mollusca of Western New York, which the writer has been able to find. There are a number of good lists of Mollusca from Eastern New York, besides those of the whole State, several of them by the veteran collector, Dr. James Lewis.

are very plentiful. Limestone is abundant in various places and of course tends to produce a snail fauna of large size. The Erie Canal is one of the best collecting localities in the State, and more species can be found in it than in any other one body of water in the region. In the spring, when it is drained, the collector may don his rubber boots and literally "wade in" after these interesting creatures. At such a time a large number of species of Unionidae may be obtained, for the canal is the metropolis of this group in the western part of the State.

The writer is under obligations to the following persons for assistance of various kinds:—

Messrs. Harry S. Hall and Herbert S. Harris for valuable aid in collecting; Mr. John Walton for information regarding Monroe County mollusks; Dr. Howard N. Lyon for a collection of shells from Cayuga County; and Prof. R. Ellsworth Call, Mr. C. W. Johnson and Prof. Henry A. Pilsbry for assistance in determining various species.

The list of stations at which collections were made is as follows: —

Station 1. Pinnacle Hill, Southeast Rochester. An esker from 100 to 200 feet above the plain upon which Rochester is built. The high hill called the Pinnacle is very steep, having a slope of from 10 to 30 degrees. The summit is well wooded, the trees extending well down the sides in a ravine, which separates the main hill from the little spur known locally as "round the world." Dead logs and leaves are very abundant, and while the soil is rather sandy in some spots, yet where the vegetation has had a chance to decay, there has been formed a rich loam, in which the mollusks love to bury themselves. Oak and maple trees predominate. July 8. Thermometer 90° in shade, collections made in the morning. Weather fine.*

Station 2. Residence of Mr. John Hall, 16 Boardman

* The data for the Pinnacle and Cobb's Hills are taken from Mr. Warren Upham's paper, Eskers near Rochester, N. Y., in Proc. Roch. Acad. Sci. 2: 181–200. 1892.

avenue, Rochester. Yard in rear of house where various species of Limax are to be found under boards and particularly under the garbage barrels.

Station 3. Wide Waters, Erie Canal, East Rochester. Shore lined with weeds and débris of various kinds; shells sticking to stones, sticks and water weeds. July 12. Collection made in the afternoon; temperature 65° to 70°; rainy.

Station 4. Genesee River Gorge, below lower falls. Banks 225 feet high, made up of the Niagara and Clinton geological formations, overlaid by about 10 feet of the Drift. Banks heavily wooded with large trees and low bushes; soil rich, mixed with pieces of decomposing limestone and shale. River very rapid; shore lined with rocks. The river is now being contaminated by sewage from the city. July 13. Temperature 60° at 8 a. m. and 85° at noon, when the clouds of the morning disappeared. Mollusks very plentiful.

Station 5. Irondequoit Bay. This body of water is an inlet from Lake Ontario, and is five miles long and from one-half to one mile in width. The rolling hills about it are from 100 to 200 feet in height and are, in most cases, heavily wooded. The bay is about 80 feet deep (maximum). The shores are lined with cat-tails (*Typha*) and sweet flag (*Acorus*). There are numerous small streams flowing into the bay and also many small bays leading off from the large bay. Irondequoit creek flows into it at its southern end. July 14. Cloudy, with occasional rains. Temperature varying from 75° to 80°. The southern part of the bay was literally covered with pond lilies (*Nymphaea*), among which many mollusks were found. The shores were everywhere covered with dead beach-shells.

Station 6. Sea Breeze, on Lake Ontario, at entrance to Irondequoit Bay. Sandy beach with ridge of sea-wrack, in which dead shells were plentiful. July 16.

Station 7. Sea Breeze; ravine near boat house on Irondequoit Bay. Heavily wooded and the ground covered with dead leaves, sticks and other débris. Ground moist. July 16. Weather fine, temperature about 80°.

Station 8. Locks in Erie Canal near Monroe Avenue bridge. Specimens collected from side of locks as the water flowed in to lift the canal boat.

Section 9. Charlotte and Summerville, Lake Ontario. These two places are situated on opposite sides of the mouth of the Genesee River, which is extended far into the lake by means of two long piers or docks. The water is shallow for a considerable distance and shells are brought by thousands over this area and deposited in long ridges of sea-wrack along the beach. This was an excellent place to find a large number of species. July 21. Weather fine and warm.

Station 10. South Park, Genesee River, near bridge. Water shallow, shore lined with rocks. Bottom sandy and muddy. Weather very fine; temperature 80°. Mollusks very common. July 22.

Station 11. New York State Fish Hatcheries, Caledonia. Grove with dead and fallen logs and numerous stones. Mollusks plentiful under boards. Stream running from fish tanks in which both Limnaea and Planorbis were found. July 23. Occasional rains. Temperature about 80°.

Station 12. Creek near Kelly's Grove. Clear and rapid. Stony bottom. Very few mollusks. July 23.

Station 13. Cobb's Hill. A part of the esker known as the Pinnacle Hills, from 75 to 125 feet in height. Heavily wooded on north side where there are several ravines. Oak and elm trees predominate. Ground moist and covered with the usual forest débris. July 27. Very rainy. Temperature 70° with a very strong wind.

Station 14. Field near canal just out of Rochester. Pupa and small Limax found under chips and sticks, and about old stumps. Rainy and rather cool.

Station 15. Canal below lock no. 65. Shore lined with flags and other water plants. July 28. Rainy.

Station 16. Long Point, Conesus Lake, in ravine. July 1, 1891. Collected by Miss Grace M. Hall.

Station 17. Owasco Lake, Cayuga County. Collected by Dr. Howard N. Lyon.

Station 18. Medina.

Station 19. Canandaigua Lake.

The last two stations are represented only by specimens in the collection of the Chicago Academy of Sciences.

In the following list the writer has deviated from the beaten path which has been trodden by conchologists in the past, but he believes that the recent conclusions of well-known students should be recognized, and adopted, wherever sufficient evidence is shown of their validity. Thus in the Unionidae, the writer has followed Mr. Charles T. Simpson; in the Pulmonata Mr. Henry A. Pilsbry; and in the Viviparidae Prof. R. Ellsworth Call. References to the publications of these gentlemen will be found elsewhere.

Class **PELECYPODA.**

Order PRIONODESMACEA.

Suborder **Naiadacea.**

Family Unionidae.*

Genus Anodonta (Bruguière em.) Lamarck.

1. Anodonta Lewisii Lea.
Station 10. A single small specimen collected.

*2. Anodonta salmonia Lea. Erie Canal.

*3. Anodonta implicata Say. Charlotte.

*4. Anodonta imbecilis Say. Irondequoit Creek.

*5. Anodonta fragilis Lam. Pittsford.

*6. Anodonta fluviatilis Dillw. Allen's Creek.

*7. Anodonta benedictii Lea. Erie Canal.

*8. Anodonta excurvata DeKay. Pittsford.

Genus Alasmodonta Say. 1819.†

9. Alasmodonta marginata Say.
Station 10. Does not seem to be common in the Genesee River. Erie Canal (Walton's list).

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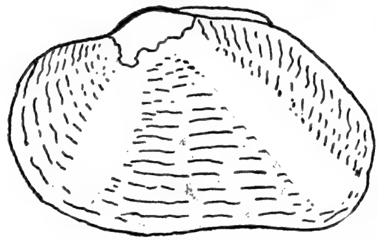
* See Simpson, Proc. U. S. National Museum **18**: 295–343. 1895.

† The present classification of the Unionidae is that of Mr. Charles T. Simpson, which will be published in the writer's report on The Mollusks of Chicago and Vicinity, now in press.

10. ALASMODONTA DELTOIDEA Lea. Erie Canal.

11. ALASMODONTA RUGOSA Barnes.
Station 10. Typical and of good size.

12. ALASMODONTA PRESSA Lea.
Station 10. This species is said to be common in the upper Genesee River, but the writer obtained only one specimen and that was both a deformed and pathologic individual of small size (length 49; breadth 18; height 29 mill.). The whole shell is much shorter and more stumpy than the typical form and there is a peculiar bulge at the posterior end. The teeth are very long and very thin. The accompanying cut is an outline figure.



A. PRESSA LEA.
PATHOLOGIC SPECIMEN.

*13. ALASMODONTA UNDULATA Say. (Walton's list).

Genus STROPHITUS Rafinesque. 1820.

14. STROPHITUS EDENTULUS Say.
Unio ferruginea Lea, Walton's list.
Station 12. One specimen found. (Long Pond and Genesee River, Walton's list.)

Genus UNIO Retzius. 1788.

*15. UNIO GIBBOSUS Barnes. Erie Canal.

Genus ANODONTOPSIS Simpson. 1898.

*16. ANODONTOPSIS SUBCYLINDRACEUS Lea. Irondequoit Creek.

*17. ANODONTOPSIS FERUSSACIANUS Lea. Erie Canal.

Genus QUADRULA (Rafinesque) Agassiz. 1852.

18. QUADRULA RUBIGINOSA Lea.
Station 10. Common, and showing no little variation in relative lengths and heights.

19. QUADRULA PLICATA Lesueur. Erie Canal.

20. QUADRULA UNDULATA Barnes. Erie Canal.

Genus LAMPSILIS Rafinesque. 1820.

*21. LAMPSILIS GRACILIS Barnes. Erie Canal.

22. LAMPSILIS IRIS Lea.

Unio novi-eboraci Lea.

Station 10. Erie Canal (Walton). This species is very common and of large size at this locality. The variation in the size and character of the rays is very great, some being perfectly straight while others are made up of square or oblong dashes, making the rays broken; the color varies from light yellow to grass green. One specimen measures 76 mill. in length. At one spot in the river these mollusks were found piled up in a great heap among the rocks, showing where a muskrat had partaken of a goodly meal.

*23. LAMPSILIS NASUTUS Say. Erie Canal.

24. LAMPSILIS LUTEOLUS Lamarck.

Stations 9, 10, 18 and 19. As is usual in this species, the specimens before the writer show a great range of variation. The individuals from station 10 are very solid, and are covered with a heavy deposit which renders them difficult to clean, besides making them very unsightly. At this locality they live in water from six inches to a couple of feet in depth, buried in the soft mud, their siphons and the extreme posterior part of their shell being the only parts of them visible. In some spots they are so close together that their shells almost touch. The sexes are very distinct in specimens from this locality, much more so than those from the canal. The shells from stations 9, 18 and 19 are smooth, polished and delicately rayed. A single specimen from station 18 has dark green rays over a yellowish-green background. The entire collection shows a surface varying from perfectly plain to very strongly rayed, and the rays vary from thread-like to very wide.

*25. LAMPSILIS VENTRICOSUS Barnes. Erie Canal.

Unio occidens Lea.

26. Lampsilis radiatus Lamarck.

Station 18. Genesee River (Walton). Does not seem to be common.

*27. Lampsilis rectus Lamarck. Erie Canal.

*28. Lampsilis rosaceus DeKay.

Of this species Mr. Walton says: " *Unio rosaceus* is quite local. I have found it only at Long Pond and the margin of Lake Ontario, between Long Pond and Charlotte. DeKay's figures are very characteristic of all I have collected."

29. Lampsilis alatus Say.

Station 10. Also one small specimen from Niagara Falls (Acad. coll.). Erie Canal (Walton). The specimens from the Genesee River are very large and fine, with a deep purple interior.

*30. Lampsilis cariosus Say. Erie Canal.

31. Lampsilis complanatus Solander.

Station 10. The specimens from this locality are very thick and heavy.

32. Unio tappanianus Lea.

Station 10. Apparently not common.

Order TELEODESMACEA.

Suborder **Veneracea.**

Family Corbiculidae.

Genus Sphaerium Scopoli.

33. Sphaerium simile Say.

Stations 5, 9, 10 and 17. Erie Canal (Walton). Very common and grows to a large size, particularly at station 10, where it may be found in great abundance along the shore in the soft mud.

34. Sphaerium stamineum Conrad.

Stations 9 and 10. Very common.

35. SPHAERIUM TRANSVERSUM Say.

Stations 4 and 10. Very common. At station 4 it may be found very abundantly just below Brewer's dock, where the specimens lie buried by thousands in the soft mud.

36. SPHAERIUM FABILE Prime.

Stations 6 and 9. Very common, particularly in the drift along the shore of Lake Ontario.

*37. SPHAERIUM PARTUMEUM Say. Genesee River.

Numbers 34, 35 and 36 are not listed by Walton.

38. SPHAERIUM RHOMBOIDEUM Say.

Station 5. Apparently not common.

Genus PISIDIUM Pfeiffer.

*39. PISIDIUM VARIABILE Prime. Brighton.

40. PISIDIUM ABDITUM Haldeman.

Station 6. Apparently very common, especially in the drift along shore.

41. PISIDIUM BAKERI Pilsbry.*

Station 9. Very common.

Class **GASTROPODA**.

Subclass ANISOPLEURA.

Superorder *Euthyneura*.

Order PULMONATA.

Suborder **Stylommatophora**.

Superfamily AGNATHA.

Family CIRCINARIIDAE.

Genus CIRCINARIA Beck, 1837.

Selenites Fisher. 1878. (Non Hope. 1840.)

42. CIRCINARIA CONCAVA Say.

Stations 10 and 11. Fairly common.

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* This is a manuscript name, which is shortly to be published by Prof. H. A. Pilsbry.

Superfamily AULACOPODA.

Family ZONITIDAE.

Genus VITREA Fitzinger.
Zonites and *Hyalina* of authors.

43. VITREA ARBOREA Say.

Stations 1, 5, 11 and 13. Pittsford (Walton). Common everywhere and with little or no variation. On the south slope of station 13 it is exceedingly abundant, just back of the Cobb house.

44. VITREA INDENTATA Say.

Stations 1 and 13. Apparently not common.

45. VITREA RADIATULA Alder.

Station 5. Not as common as *arborea*. Specimens from this locality are large and very fine.

†46. VITREA BINNEYANA Morse.*

Genus OMPHALINA Rafinesque.

47. OMPHALINA FULIGINOSA Griff.

Stations 1 and 5. Cayuga Lake Valley (Banks). This species is found in great abundance at station 1, under dead leaves and old logs; frequently found buried in the earth. The specimens are very dark colored and highly polished.

48. OMPHALINA INORNATA Say.

Station 16. Pittsford (Walton). Cayuga (Banks). Apparently not common. The single specimen collected is very light colored.

†49. OMPHALINA LAEVIGATA Pfr.

†50. OMPHALINA FRIABILIS Binney.

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* Names marked with a dagger are taken from Mr. Banks' paper in The Nautilus 5: 137. This is a list of The Land Mollusca of the Cayuga Valley.

Genus Gastrodonta Albers.*

†51. Gastrodonta ligera Say.

52. Gastrodonta intertexta Binney.

Station 1. Pittsford (Walton). Cayuga (Banks). Rather common, under fallen trees and débris of various kinds.

53. Gastrodonta suppresa Say.

Station 5. Pittsford (Walton). Not common.

*†54. Gastrodonta multidentata Binney. Rochester and Cayuga.

*†55. Gastrodonta nitida Müller.

Stations 5 and 7. Monroe County (Walton) and Cayuga (Banks). Very common near the boat house at Station 5.

*†56. Gastrodonta minuscula Binney.

*57. Gastrodonta limatula Ward.

†58. Gastrodonta milium Morse.

Genus Conulus Fitzinger.

*†59. Conulus fulvus Drap.

Pittsford (Walton); Cayuga (Banks).

Family Limacidae.

Genus Limax Linné.

60. Limax maximus Linné.

61. Limax flavus Linné.

Station 2. East Rochester (Walton); Cayuga (Banks). Very common and of large size. Two specimens of *maximus* measured 150 and 165 mill. in length; and two of *flavus* measured 91 and 130 mill. in length.

62. Limax agrestis Linné.

Stations 2 and 14. East Rochester (Walton).

* For a consideration of these genera, see Pilsbry, Proc. Phil. Acad. Sci. 1894: 11–31.

63. Limax campestris Binney.

Stations 1, 2, 3, 5, 11, 13 and 17. Found commonly everywhere.

Family Philomycidae.

Genus Philomycus Rafinesque.

*†64. Philomycus carolinensis Bosc.

*65. Philomycus dorsalis Binney.

Family Vitrinidae.

Genus Vitrina Drap.

*66. Vitrina limpida Gould.

Family Endodontidae.

Genus Pyramidula Fitzinger.
Patula Held.

67. Pyramidula alternata Say.

Stations 1, 4, 5, 7, 10, 11, 13 and 17. Rochester (Walton); Cayuga (Banks). This is the most common land snail, and shows the usual variation in height of spire, coloration and coarseness of ribbing.

68. Pyramidula perspectiva Say.

Station 13. Pittsford (Walton); Cayuga (Banks). But one specimen was found, which measured 10 mill. in diameter.

69. Pyramidula striatella Anthony.

Stations 1, 7, 11 and 13. Pittsford (Walton); Cayuga (Banks). Common everywhere.

Section Helicodiscus Morse.

70. Pyramidula lineata Say.

Station 5. Rochester (Walton); Cayuga (Banks). Common.

Superfamily Holopoda.

Family Helicidae.

Genus Vallonia Risso.

71. Vallonia pulchella Müller.

Station 4. Pittsford (Walton); Cayuga (Banks). Common everywhere.

72. Vallonia costata Müller.

Station 21. Common and strongly ribbed.

Genus Polygyra (Say). 1818; Pilsbry. 1889.

Section Mesodon Rafinesque.

73. Polygyra albolabris Say.

Stations 1, 5, 7, 13, 16 and 17. Rochester (Walton); Cayuga (Banks). Very common.

A form with a parietal tooth is found at Pittsford (var. *dentata* of Walton's list).

74. Polygyra thyroides Say.

Stations 4, 11 and 18. Rochester (Walton); Cayuga (Banks). Common everywhere.

The young of this and the preceding species are very difficult, if not well-nigh impossible, to separate.

75. Polygyra sayii Binney.

Station 1. Pittsford (Walton); Cayuga (Banks). Apparently quite rare.

†76. Polygyra dentiferum Binney.

Section Stenotrema Rafinesque.

77. Polygyra hirsuta Say.

Station 7. Rochester (Walton); Cayuga (Banks). Common.

78. Polygyra Monodon Rack. Plate X. fig. 6.

Stations 1, 5 and 13. Rochester (Walton); Cayuga (Banks). A single specimen, from the Pinnacle, has two teeth on the parietal wall and six old peristomes crowded together. The parietal teeth are long, thin and curved, and the whole shell is very much distorted.

*78a. POLYGYRA MONODON FRATERNA Say.

*79. POLYGYRA LEAII Ward.

Section TRIODOPSIS Rafinesque.

80. POLYGYRA PALLIATA Say.
Station 16. Pittsford (Walton); Cayuga (Banks).

POLYGYRA TRIDENTATA Say.
Stations 1, 4, 5, 7, 13 and 17. Rochester (Walton); Cayuga (Banks). This species is very common, especially at Station 1, where it is found attached to the under side of logs and sticks. It is subject to very great variation and several varieties have been made; whether there are additional varieties or whether those named are worthy of distinction is the question that confronts the student. In the present lot there are the following forms or varieties.* The novelties herein described are apparently fully adult specimens.

81. P. TRIDENTATA Say. Typical (Plate X. fig. 1).
This form is characterized by two large peristome teeth and a small, almost straight parietal tooth which is directed between the two peristome teeth.

81a. P. TRIDENTATA JUXTIGENS Pilsbry. (Plate X. fig. 3.)
Station 1. Similar to the typical form, but the distance between the teeth on the peristome is considerably less and the parietal tooth is much larger, is curved and is directed toward the upper tooth on the peristome.

81b. P. TRIDENTATA ——— (Plate X. fig. 4.)
Station 1. In this form (which is a variety of the above) the teeth on the peristome are very small and are very wide apart; the tooth on the parietal wall is like the last variety.

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* See Pilsbry, Proc. Phil. Acad. Sci. 1894: 11–31.

81c. P. TRIDENTATA BIDENTATA var. nov. (Plate X. fig. 2.) Station 1. Characterized by a perfectly smooth parietal wall and two teeth on the peristome, similar to those of typical *tridentata*. A half dozen specimens of this form have been seen.

81d. P. TRIDENTATA UNIDENTATA var. nov. (Plate X. fig. 5.) Station 1. In this form, of which a number of specimens have been seen, the peristome is perfectly plain and rounded, and the parietal tooth is small and points toward the upper part of the peristome.

81e. P. TRIDENTATA EDENTILABRIS Pilsbry.
In this form (of which no specimens were found at this locality) there are no lip teeth.*

*81f. P. TRIDENTATA FRAUDULENTA Pilsbry.
This is the *fallax* of most authors, but, according to Mr. Pilsbry, it is not the true *fallax* of Say, which is the *introferens* of Bland. It is characterized by a very heavy parietal tooth, a large bifid upper tooth on the peristome and a much smaller tooth on the base of the latter. The teeth nearly fill up the aperture.†

Genus PUNCTUM Morse.

†82. PUNCTUM PYGMAEUM MINUTISSIMUM Lea.

Family PUPIDAE.

Genus STROBILOPS Pilsbry.
Strobila Morse.

*†83. STROBILOPS LABYRINTHICA Say.

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* See Pilsbry, The Nautilus, 7^{12}: 140. 1894.

† The *Tachea hortensis* Müller, recorded by Mr. Walton, should not be included in the list of Western New York shells, because it was a stray specimen which had gotten away from Vick's greenhouse.

Genus Pupa Drap.*

Subgenus *Pupilla* Leach.

84. Pupa muscorum Linné.

Stations 5, 10 and 17. Brighton (Walton). Specimens from station 5 are very large and light colored; those from station 10 are small, dark chestnut-colored and are found under chips near the base of the bank opposite Brewer's landing. Apparently very common.

Subgenus *Leucocheila* Alb. and Mart.

*85. Pupa fallax Say.

Subgenus *Columella* Mart.

*†86. Pupa edentula.

P. simplex Gld.

Irondequoit (Walton); Cayuga (Banks).

Subgenus *Bifidaria* Sterki.

*†87. Pupa corticaria Say. Pittsford (Walton).

Section Albinula Sterki.

*†88. Pupa armifera Say.

*†89. Pupa contracta Say.

Station 11. Common. The specimens are smaller than the typical and approach *P. holzingeri* Sterki. The parietal tooth is somewhat smaller and does not enter as far into the aperture as in the typical form. I have not found this variety common.

Section Bifidaria s. str.

*†90. Pupa rupicola Say.

Section Vertigopsis Ckll. Mss.

91. Pupa pentodon Say.

Station 14. Rochester (Walton); Cayuga (Banks). Common.

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* See Sterki, The Nautilus 6^1: 2–8. 1892.

Subgenus *Angustula* Sterki.

*†92. Pupa milium Gould.

Genus Vertigo Müller.

*†93. Vertigo ovata Say.

†94. Vertigo gouldii Binney.

†95. Vertigo bollesiana Morse.

Family Stenogyridae.

Genus Ferussacia Risso.

Subgenus *Cionella* Jeffreys.

96. Ferussacia subcylindrica Linné.

Stations 4, 5 and 11. East Rochester (Walton); Cayuga (Banks). Common.

Family Succineidae.

Genus Succinea Drap.

*†97. Succinea obliqua Say. Pittsford (Walton).

*97a. Succinea obliqua totteniana Lea.

98. Succinea avara Say.

Station 10. Rochester (Walton); Cayuga (Banks). Common.

*99. Succinea aurea Lea.

100. Succinea ovalis Gould.

Stations 3, 5, 10, 11, 15 and 17. Charlotte (Walton); Cayuga (Banks). Very common and variable in color, some specimens being of a rich golden hue. The specimens collected vary from very narrow to rather wide. The species is found in great numbers along the shores of lakes and rivers, either among the drift or crawling up the stems of the flags which line the shore. The latter case is typical of station 5.

Suborder **Basommatophora.**

Superfamily AKTEOPHILA.

Family AURICULIDAE.

Genus CARYCHIUM Müller.

101. CARYCHIUM EXIGUUM Say.
Station 5. Rochester (Walton); Cayuga (Banks).

Superfamily HYGROPHILA.

Family LIMNAEIDAE.

Subfamily LIMNAEINAE.

Genus LIMNAEA Lamarck.

102. LIMNAEA STAGNALIS Linné.
Stations 3 and 15. Brighton (Walton). Very abundant and of large size; found crawling over sticks and other débris in a few inches of water at station 3. There is considerable variation in the form of the aperture, some being almost round while others are long and narrow. The spires in these specimens, however, are of about the same length. Some individuals have fine spiral lines encircling the whorls.

Section RADIX Mont.

*103. LIMNAEA COLUMELLA Say.

Section LIMNOPHYSA Fitz.

*104. LIMNAEA REFLEXA Say.

105. LIMNAEA PALUSTRIS Müller.
Stations 3, 5, 6, 9, 10, 11 and 17. Erie Canal (Walton). Common and variable. The *L. elodes* Say of Walton's list is a synonym.

106. LIMNAEA CATASCOPIUM Say.
Stations 3, 4, 8 and 15. Erie Canal (Walton). Very common and exceedingly variable. The typical *catascopium* is a

stumpy shell with the aperture longer than the spire. Another form occurs which has a longer spire, as long as the aperture, and runs into *L. expansa* Hald., which latter does not seem to me to = *L. palustris* Müller, but is rather a variety of *catascopium*. A peculiar monstrosity was found by Master Hall at station 4, in which there was a large longitudinal ridge behind the peristome, the latter being much expanded, flaring, and the aperture twisted out of shape. *Catascopium* is found on stones and sticks in water from a few inches to several feet in depth.

107. Limnaea desidiosa Say.
Stations 3, 5, 6, 9, 11 and 15. Monroe County (Walton). Found commonly on sticks and stones, and occasionally in *Spirogyra*. Considerable variation is found among the specimens collected, some being long and narrow, while others are short and stumpy. The aperture is sometimes a little longer than the spire.

*108. Limnaea caperata Say. Pittsford (Walton).

*109. Limnaea pallida Adams. Erie Canal (Walton).

110. Limnaea humilis Say.
Station 11. Common and typical.

Subfamily Planorbinae.

Genus Planorbis Guettard.

Section Planorbella Hald.

111. Planorbis campanulatus Say.
Stations 5, 6 and 9. Pittsford (Walton). Very common.

Section Helisoma Swainson.

112. Planorbis trivolvis Say.
Stations 3, 4, 5, 6, 8, 10, 15 and 17. Charlotte (Walton). Common everywhere and extremely variable. Very frequently distorted.

113. PLANORBIS BICARINATUS Say.

Stations 5, 6, 9 and 17. Rochester (Walton). Very common everywhere and also subject to great deformity.

Subgenus *Gyraulus* Agassiz.

114. PLANORBIS DEFLECTUS Say.

Stations 5, 6 and 11. Brighton (Walton). Common and typical.

*115. PLANORBIS HIRSUTUS Gould.

Mr. Walton reports finding this species in the Erie Canal.

116. PLANORBIS PARVUS Say.

Stations 5 and 6. Charlotte (Walton). Very common everywhere. Found in *Spirogyra*.

Genus SEGMENTINA Fleming.

Subgenus *Planorbula* Hald.

117. SEGMENTINA ARMIGERA Say.

Station 5. Brighton (Walton).

Subfamily ANCYLINAE.

Genus ANCYLUS Geoffroy.

*118. ANCYLUS PARALLELUS Haldeman. Charlotte.

*119. ANCYLUS TARDUS Say. Irondequoit.

*120. ANCYLUS RIVULARIS Say. Genesee River.

Family PHYSIDAE.

Genus PHYSA Drap.

121. PHYSA HETEROSTROPHA Say.

Stations 3, 4, 5, 6, 8, 9, 10 and 11. Common everywhere and exceedingly variable.

A recent study of this genus convinces the writer that of the seventy odd species described at the present time, there are really but ten or a dozen valid names. The following will all prove to be synonyms of the present species, and there are several other names which will probably have to be added to this list: *gyrina* Say, *elliptica* Lea, *aurea* Lea, *Sayii* Tappan, *Troostiana* Lea, *fontana* Hald., *Hildrethiana* Lea, *inflata* Lea, *cylindrica* Newcomb, *anatina* Lea, *Forsheyi* Lea, *Saffordii* Lea, *Haunii* Lea, *parva* Lea, *Nicklinii* Lea, *altonensis* Lea, *Febigerii* Lea, *Warrenana* Lea, *Halei* Lea, *Whitei* Lea, *Grosvenorii* Lea, *lata* Tryon, *primeana* Tryon, *oleacea* Tryon, *coniformis* Tryon, *deformis* Currier and *albofilata* Ancey. The above seems like a tremendous synonymy, but it is probable that most, if not all, of these names will stand as they are written.

122. PHYSA ANCILLARIA Say.

Station 17. Rochester (Walton). This species is closely related to *heterosotropha*, and it may be but a variety of that species. It is always a wider and more robust form, and is distinctly shouldered, the latter being a character lacking in the former species.

Genus APLEXA Fleming.

*123. APLEXA HYPNORUM Linné. Pittsford.

Superorder *Streptoneura*.

Order CTENOBRANCHIATA.

Suborder **Orthodonta**.

Superfamily TAENIOGLOSSA.

Family PLEUROCERIDAE.

Genus PLEUROCERA Rafinesque.

124. PLEUROCERA SUBULARE Lea.

Stations 5 and 6. Common.

Genus ELIMIA H. and A. Adams, 1854.

Goniobasis Lea, 1862.

*125. ELIMIA VIRGINICA Say. Erie Canal.

*125a. Elimia virginica multilineata Say. Erie Canal.

126. Elimia livescens Menke.

Station 10. Erie Canal (Walton). Very common in water from six to eighteen inches in depth, on or in a soft carbonaceous mud. Specimens are always covered with a deposit of algae in this locality. The specimens collected are very uniform.

*126a. Elimia livescens depygis Say. Irondequoit.

*127. Elimia semicarinata Say. Irondequoit.

Family Bissoidae.

Subfamily Bythiniidae.

Genus Rythinia Gray.

128. Bythinia tentaculata Linné. (Plate X, figs. 7–10.)

Stations 3, 4, 6, 9 and 15. Erie Canal (Walton). Very common everywhere.

A number of specimens were obtained alive, and the writer is able to give a figure of the dentition from an American specimen. The central tooth is rather broader than long, very much lobed at either end, the ends of the lobes rounded. The usual rounded projection from the center of the lower surface is present. The reflection is short and wide and 7-cuspid, the center cusp large and rounded and the three side cusps short, triangular and very sharp. The denticles on the lateral lobes are 6–7 in number and are bluntly rounded. The intermediate tooth is squarish, produced at the lower outer corner and 7-dentate, the third cusp from the left side being large and roundly pointed, and the side cusps, two on the left and four on the right, are small and acutely triangular. The lateral teeth are long and narrow and rounded at their lower extremity. The reflections are short and wide, the first 12 and the second 16 cuspid. The writer was not, unfortunately, able to count the number of rows of teeth. The writer regrets that he does not have access to European publications, in which the radula of this species is figured, for comparison.

Family Amnicolidae.

Genus Amnicola G. & H.

129. Amnicola limosa Say.
Stations 6 and 9. Genesee River (Walton). Common.

*130. Amnicola porata Say. Erie Canal.

*131. Amnicola orbiculata Lea.

*132. Amnicola pallida Hald.

*133. Amnicola granum Say.

134. Amnicola lustrica Pilsbry. Station 5. Rare.

Genus Cincinnatia Pilsbry.

135. Cincinnatia obtusa Lea.
Stations 6 and 9. Common.

136. Cincinnatia cincinnatiensis Anthony.
Station 9. Only a single specimen found.

Genus Gillia Stimpson.

137. Gillia altilis Lea.
Station 9. Erie Canal (Walton). Rather common.

Genus Somatogyrus Gill.

138. Somatogyrus subglobosus Say.
Station 9. Common.

Family Valvatidae.

Genus Valvata Müller.

139. Valvata sincera Say.
Stations 5, 6 and 9. Erie Canal (Walton). Very common, and subject to considerable variation.

140. Valvata tricarinata Say.
Stations 3, 5 and 9. Very common and exceedingly variable, being either uni-, bi- or tricarinate.

141. VALVATA OBTUSA Drap.

Station 9. Very common. This is the first record of the occurrence of this species in this country. It is a common European species.

Subgenus *Lyogyrus* Gill.

*142. VALVATA PUPOIDEA Gould.

Mr. Walton reports having found this species near Rochester.

Family VIVIPARIDAE.

Genus VIVIPARA Lamarck.

*143. VIVIPARA CONTECTOIDES W. G. Binney.

Mr. Walton reports finding a large number of specimens of this species in the Erie Canal near Pittsford. This is the only record of this species being found in this part of New York.

Genus CAMPELOMA Rafinesque.

*144. CAMPELOMA PONDEROSUM Say. Erie Canal.

145. CAMPELOMA DECISUM Say.

Station 10. Erie Canal (Walton). Very common, buried in soft mud.

*146. CAMPELOMA GENICULUM Conrad. Erie Canal.

147. CAMPELOMA RUFUM Haldeman.

Station 10. Very common, associated with *decisum*. Erie Canal (Walton).

*148. CAMPELOMA INTEGRUM DeKay. Erie Canal.

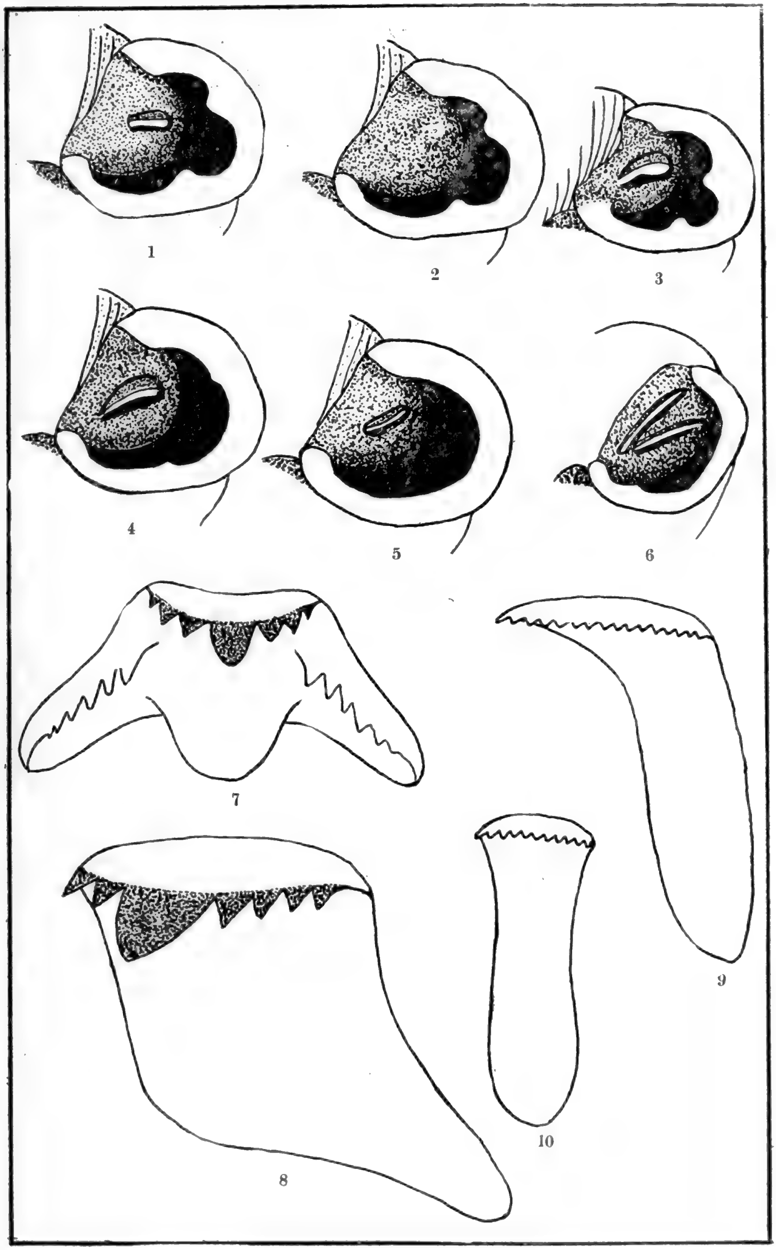
*149. CAMPELOMA OBESUM Lewis. Erie Canal.

EXPLANATION OF ILLUSTRATIONS.

PLATE X.

1, *Polygyra tridentata* Say. Pilsbry, Proc. Phil. Acad. Sci. 1894. *pl. 1. f. 7.*— 2, *P. tridentata bidentata* Baker. Original.— 3, *P. tridentata juxtigens* Pilsbry, Proc. Phil. Acad. Sci. 1894. *pl. 1. f. 8.*— 4, *P. tridentata* ——— Original.— 5, *P. tridentata unidentata* Baker. Original.— 6, *P. monodon* Rack., double parietal tooth. Original.— 7–10, *Bythinia tentaculata* Linné. 7, Central tooth.— 8, Intermediate tooth.— 9, First lateral.— 10, Second lateral. All original.

Issued March 22, 1898.



POLYGYRA AND BYTHINIA.

THE EFFICIENCY OF GEARING UNDER FRICTION.

CALVIN M. WOODWARD.

1. The energy lost through the friction of gears, is often ignored, and none of the treatises on Applied Mathematics give a satisfactory treatment of the subject. Moseley's elegant discussion is a little involved; he deals too much with conditions "behind the line of centers;" he fails to give exact results in a finite form; he furnishes no convenient formulae for showing at a glance the effect of the size of the rolling circle in the case of epicycloidal teeth; and he gives no convenient material for comparing the efficiency of epicycloidal teeth with the efficiency of involute teeth.

The following discussion was in substance given to my class nearly two years ago; I have however recently reduced my equations to such form that the efficiencies of the two kinds of teeth can readily be compared without the trouble of numerical examples.

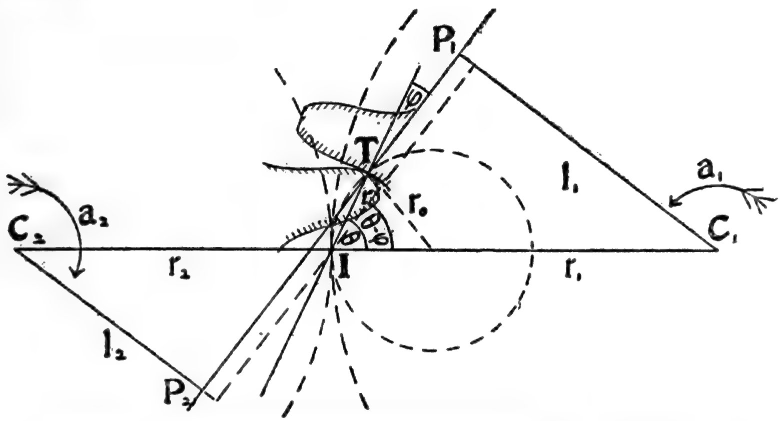


Figure 1, Showing two teeth in action during the "Approach."

2. *General Formulae for all Teeth.* Let Fig. 1 represent the geometrical conditions in a plane perpendicular to a pair of parallel axes. C_1 and C_2 are the centers of two wheels, I, their pitch point, r_1 and r_2 their radii, and T the point of contact of two teeth. TI is the common normal to the teeth in

action, and θ the angle the normal makes with the line of centers. The arrows show the directions of rotations, C_1 being the driver.

While the friction is not a function of the velocity, it is convenient to employ their angular velocities a_1 and a_2. During the "approach" to the pitch point the two teeth are sliding towards each other, the velocity of sliding being measured by the familiar expression $r\,(a_1 + a_2)$, r being the distance of the point of contact from the pitch point. Letting the co-efficient of friction be f, it is evident that the line of resultant action between the teeth makes an angle φ with the normal such that $\tan \varphi = f$. The action of the driving tooth is then along the line P_1TP_2. The magnitude of that action we will call P; so that the driving moment is $Pl_1 = M_1$; and the moment transmitted to the follower is $M_2 = Pl_2$. From the notation shown in Fig. 1, it is easily seen that

$$\left.\begin{aligned} l_1 &= r_1 \sin(\theta - \varphi) + r \sin \varphi \\ l_2 &= r_2 \sin(\theta - \varphi) - r \sin \varphi \end{aligned}\right\} (1).$$

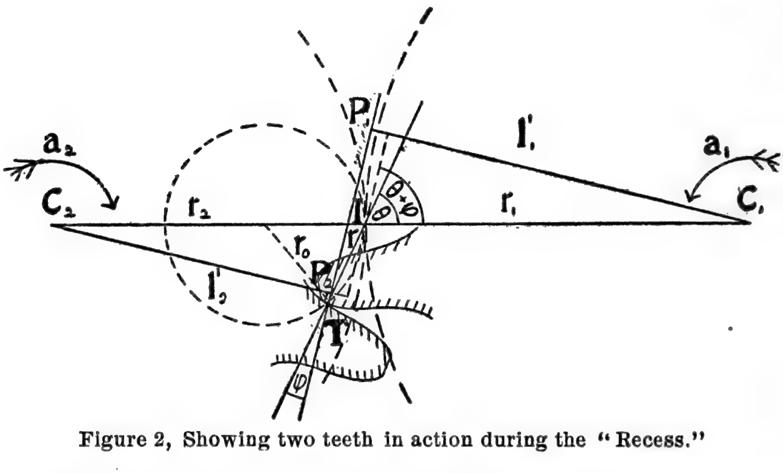


Figure 2, Showing two teeth in action during the "Recess."

After the point of contact has passed the pitch point, and the teeth are separating, the line of resultant action is on the other side of the normal, as is shown in Fig. 2. In this case

$$\left.\begin{aligned} l_1' &= r_1 \sin(\theta + \varphi) + r \sin \varphi \\ l_2' &= r_2 \sin(\theta + \varphi) - r \sin \varphi \end{aligned}\right\} (2).$$

Now the friction actually overcome in either case is $P \sin \varphi$, and since the velocity of sliding is $r\,(a_1 + a_2)$, the amount of friction overcome, or the energy lost, during the time dt is

$$dU = P \sin \varphi \; (a_1 + a_2)\, r dt \qquad (3).$$

These formulae hold at all times and for all kinds of teeth that are of correct outlines.

3. *Epicycloidal Teeth.* Let the driving moment M_1 be constant, and let the teeth be epicycloidal, described by a rolling circle with radius r_0. Also let q be the "arc of approach" *i. e.* the arc of one of the pitch circles which will pass the pitch point while the point of contact T is moving to the pitch point.

It is evident that during the approach dq is negative, and that

$$a_1 r_1 dt = a_2 r_2 dt = -\, dq;$$

hence

$$(a_1 + a_2)\, dt = -\left(\frac{1}{r_1} + \frac{1}{r_2}\right) dq.$$

But from the figure,

$$r = 2 r_0 \cos \theta, \text{ and } q = r_0\,(\pi - 2\theta),$$

hence

$$dq = -\, 2 r_0 d\theta, \text{ and since } P = M_1 \div l_1$$

we have from (I) and (III)

$$dU_1 = \frac{M_1 \sin \varphi}{l_1} \left(\frac{1}{r_1} + \frac{1}{r_2}\right) 4 r_0^2 \cos \theta d\theta$$

$$U_1 = 4 r_0^2 \left(\frac{1}{r_1} + \frac{1}{r_2}\right) M_1 \sin \varphi \int_{\theta_1}^{\frac{\pi}{2}} \frac{\cos \theta d\theta}{r_1 \sin (\theta - \varphi) + r \sin \varphi}$$

$$= 4 \frac{r_0^2}{r_1} \left(\frac{1}{r_1} + \frac{1}{r_2}\right) M_1 f \int_{\theta_1}^{\frac{\pi}{2}} \frac{d\theta}{\tan \theta - \left(1 - \frac{2 r_0}{r_1}\right) f} \qquad (4)$$

by simplifying and putting $\tan \varphi = f$. This formula gives the energy lost during the "approach," the initial value of θ being θ_1.

Let $\left(1 - \frac{2r_0}{r_1}\right) f = k$ in the above. Integrating as indicated

$$U_1 = 4\frac{r_0^2}{r_1}\left(\frac{1}{r_1} + \frac{1}{r_2}\right) M_1 f$$

$$\times \left[\frac{-\log_e (\sin \theta_1 - k \cos \theta_1) - k\left(\frac{\pi}{2} - \theta_1\right)}{1 + k^2}\right] \quad (5).$$

4. The above assumes that but a single pair of teeth are in action. It does not appear that the introduction of more pairs would affect the ratio I am aiming to get provided the pairs are in all respects alike, and the moment of the action of each driving tooth be constant.

5. During the "recess" dq is positive and we have

$$(a_1 + a_2)\, dt = \left(\frac{1}{r_1} + \frac{1}{r_2}\right) dq$$

and (3) becomes

$$d\,U_2 = 4r_0^2 M_1 \sin \varphi \left(\frac{1}{r_1} + \frac{1}{r_2}\right)\left(-\frac{\cos \theta d\theta}{l_1'}\right)$$

Substituting the value of l'_1, simplifying and integrating from $\frac{\pi}{2}$ to θ_2 we get

$$U_2 = \frac{4r_0^2}{r_1}\left(\frac{1}{r_1} + \frac{1}{r_2}\right) M\ f$$

$$\times \left[\frac{k'\left(\frac{\pi}{2} - \theta_2\right) - \log_e (\sin \theta_2 + k' \cos \theta_2)}{1 + k'^2}\right] \quad (6).$$

in which $$k' = \left(1 + \frac{2r_0}{r_1}\right) f.$$

This formula gives the energy lost during the recess.

Ratio of Energy Lost to Energy Exerted. The whole energy lost during the action of one pair of teeth is $U_1 + U_2$. The total energy exerted by the driver during the same time is M_1 multiplied by the arc (radius measure) described by the driver during the action. If we let the wheels have n_1 and n_2 teeth, the arc required is $\frac{2\pi}{n_1}$, and hence

$$U = M_1 \frac{2\pi}{n_1} \qquad (7).$$

The ratio of work lost to energy exerted (which ratio I will call R) is

$$R = \frac{U_1 + U_2}{U}$$

But the co-efficient

$$\frac{4r_0^2}{r_1}\left(\frac{1}{r_1} + \frac{1}{r_2}\right) = 4\left(\frac{r_0}{r_1}\right)^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)n_1.$$

Substituting this, and (5), (6) and (7), we get

$$R = \left(\frac{1}{n_1} + \frac{1}{n_2}\right)\frac{2n_1^2 f}{\pi}.\left(\frac{r_0}{r_1}\right)^2\left[\frac{-\log_e(\sin\theta_1 - k\cos\theta_1) - k\left(\frac{\pi}{2} - \theta_1\right)}{1 + k^2} + \frac{-\log_e(\sin\theta_2 + k'\cos\theta_2) + k'\left(\frac{\pi}{2} - \theta_2\right)}{1 + k'^2}\right] \qquad (8)$$

in which $\quad k = \left(1 - \frac{2r_0}{r_1}\right)f, \quad k' = \left(1 + \frac{2r_0}{r_1}\right)f.$

The efficiency of the combination is found by subtracting R from unity.

$$\text{Efficiency} = 1 - R \qquad (9).$$

Formula (8) is general and exact when but one pair of teeth is in action at a time.

7. In applying (9) to an ideal case the sum of θ_1 and θ must be calculated from the equation

$$\theta_1 + \theta_2 = \frac{\pi}{n_1}\left(n_1 - \frac{r_1}{r_0}\right) \qquad (10)$$

in which the action of only one pair at a time is assumed, and from some other assumed relation between them. If *two* pairs of teeth are *always* in action, the actual numbers of teeth on the wheels must be divided by 2 in order to get the n_1 and n_2 of the formula. If *three* pairs are always in action, we must divide by 3. Thus suppose the actual numbers of teeth in a pair of gears are 36 and 90, and that *three* pairs are constantly in action; then $n_1 = 12$ $n_2 = 30$.*

8. *Reduction of the value of R to a more convenient form.* If, as is usual, the arc of approach is made equal to the arc of recess, we shall have

$$\theta_1 = \theta_2 = \frac{\pi}{2} - \frac{\pi r_1}{n_1 2 r_0}$$

Now for convenience let the quantity $\frac{2r_0}{r_1} = e$. This quantity appears in the values of k, k', θ_1 and θ_2.

Then $\theta = \frac{\pi}{2} - \frac{\pi}{n_1 e}$; $k = (1 - e)f$; $k' = (1 + e)f$. (11).

Substituting this value of θ for θ_1 and θ_2 in (8), and e for its value in the co-efficient of the same equation we have,

$$R = \left(\frac{1}{n_1} + \frac{1}{n_2}\right)\frac{n_1^2 e^2 f}{2\pi}\left[\frac{-\log\left(\cos\frac{\pi}{n_1 e} - k\sin\frac{\pi}{n_1 e}\right) - k\frac{\pi}{n_1 e}}{1 + k^2} + \frac{k'\left(\frac{\pi}{n_1 e}\right) - \log\left(\cos\frac{\pi}{n_1 e} + k'\sin\frac{\pi}{n_1 e}\right)}{1 + k'^2}\right]$$

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* The case in which two pairs are in action a part of the time and one pair a part is not provided for by my formula. For such a case the "approach" would consist of two epochs during the first of which M_1 would be double its value in the second epoch. The resulting value of R would thus contain four definite integrals instead of two. I have not thought it worth while to elaborate the result.

If now we develop the first logarithm by McLaurin's theorem, we get a term which cancels out the term $\frac{k\pi}{n_1 e}$ and the remainder is exactly divisible by $1 + k^2$. The result, which is the value of the first fraction, is

$$\frac{\pi^2}{2n_1^2e^2} + \frac{k}{3}\frac{\pi^3}{n_1^3e^3} + \frac{1+3k^2}{12}\cdot\frac{\pi^4}{n_1^4e^4} + \frac{k(2+3k^2)}{15}\frac{\pi^5}{n_1^5e^5} + \frac{2+15k^2+15k^4}{90}\frac{\pi^6}{n_1^6e^6} + \&c.$$

The second fraction treated in the same way gives

$$\frac{\pi^2}{2n_1^2e^2} - \frac{k'\pi^3}{3n_1^3e^3} + \frac{1+3k'^2}{12}\frac{\pi^4}{n_1^4e^4} - \frac{k'(2+3k'^2)}{15}\frac{\pi^5}{n_1^5e^5} + \&c.$$

Adding these and withdrawing $\frac{\pi^2}{n_1^2e^2}$ from the brackets, we get

$$R = \left(\frac{1}{n_1} + \frac{1}{n_2}\right)\frac{\pi f}{2}\left[1 - \frac{k'-k}{3}\frac{\pi}{n_1 e} + \frac{\pi^2}{6n_1^2e^2} + \frac{k^2+k'^2}{4}\frac{\pi^2}{n_1^2e^2} - \frac{2(k'-k)}{15}\frac{\pi^3}{n_1^3e^3} - \&c.\right]$$

but $k' - k = 2ef$, $k^2 + k_1^2 = 2(1+e^2)f^2$, hence

$$R = \left(\frac{1}{n_1} + \frac{1}{n_2}\right)\frac{\pi f}{2}\left[1 - \frac{2\pi f}{3n_1} + \frac{\pi^2}{6n_1^2e^2} + \frac{\pi^2 f^2}{2n_1^2e^2} + \frac{\pi^2 f^2}{2n_1^2} - \frac{4\pi^3 f}{15n_1^3e^2} - \&c.\right] \quad (12).$$

9. In formula (12) the values of n_1 and n_2 are to be found as explained in § 7. The value of $e = \frac{2r_0}{r_1}$ is always unity or less. The terms in the series are arranged in order of magnitude for common values of n_1, e, and f. The character "&c." covers only very small quantities. The common approximate formula stops with the first term of the series.

The fourth and fifth terms show that the greater the value of r_0, the less the loss.

10. *Involute Teeth.* Returning to (3) and substituting for P and l_1 we have for the approach

$$dU_1 = \left(\frac{1}{r_1} + \frac{1}{r_2}\right) M_1 \sin\varphi \frac{-rdq}{r\sin\varphi + r_1\sin(\theta - \varphi)}$$

But in the case of involute teeth both θ and φ are constant, and $r = q\sin\theta$; hence

$$U_1 = \left(\frac{1}{r_1} + \frac{1}{r_2}\right) M_1 \int_0^{q_1} \frac{qdq}{q + \frac{r_1\sin(\theta - \varphi)}{\sin\theta\sin\varphi}}.$$

Letting $\frac{r_1\sin(\theta-\varphi)}{\sin\theta\sin\varphi} = h$, and integrating we have

$$U_1 = \left(\frac{1}{r_1} + \frac{1}{r_2}\right) M_1 \left[q_1 - h\log\left(1 + \frac{q_1}{h}\right)\right] \qquad (13).$$

11. During the recess, we use l_1' from (2), and putting

$$h' = \frac{r_1\sin(\theta + \varphi)}{\sin\theta\sin\varphi}$$

we get by a similar process

$$U_2 = \left(\frac{1}{r_1} + \frac{1}{r_2}\right) M_1 \left[2q - h'\log\left(1 + \frac{q_2}{h'}\right)\right] \qquad (14).$$

12. If as is usual we let $q_1 = q_2 = q$, the total energy lost becomes

$$U_1 + U_2 = M_1\left(\frac{1}{r_1} + \frac{1}{r_2}\right)\left[2q - h\log\left(1 + \frac{q}{h}\right) - h'\log\left(1 + \frac{q}{h'}\right)\right]$$

The energy exerted by the driver during this action is

$$U = \frac{2q}{r_1} M_1$$

and the ratio of energy lost to energy exerted is

$$R = \frac{U_1 + U_2}{U} = \left(\frac{1}{r_1} + \frac{1}{r_2}\right)\frac{r_1}{2q}$$

$$\left[2q - h \log\left(1 + \frac{q}{h}\right) - h' \log\left(1 + \frac{q}{h'}\right)\right] \quad (15).$$

Let n_1 and n_2 represent the numbers of teeth in the driver and follower. Then, but one pair of teeth being in action at a time,

$$q = \frac{\pi r_1}{n_1}.$$

When the obliquity is as small as possible,

$$\text{max. } r = q \sin\theta = r_1 \cos\theta$$

hence $$\tan\theta = \frac{r_1}{q} = \frac{n_1}{\pi}, \text{ and}$$

$$h = r_1 \frac{\sin(\theta - \varphi)}{\sin\theta \sin\varphi} = r_1(\cot\varphi - \cot\theta) = r_1 \frac{n_1 - \pi f}{n_1 f}$$

$$h' = r_1 \frac{\sin(\theta + \varphi)}{\sin\theta \sin\varphi} = r_1(\cot\varphi + \cot\theta) = r_1 \frac{n_1 + \pi f}{n_1 f}$$

$$\left(\frac{1}{r_1} + \frac{1}{r_2}\right)\frac{r_1}{2q_1} = \left(\frac{1}{n_1} + \frac{1}{n_2}\right)\frac{n_1^2}{2\pi r_1}$$

Substituting the above values in (15) and removing r_1 from the brackets, we have

$$R = \left(\frac{1}{n_1} + \frac{1}{n_2}\right)\frac{n_1^2}{2\pi}\left[\frac{2\pi}{n_1} - \frac{n_1 - \pi f}{n_1 f} \log\left(1 + \frac{\pi f}{n_1 - \pi f}\right)\right.$$

$$\left. - \frac{n_1 + \pi f}{n_1 f} \log\left(1 + \frac{\pi f}{n_1 + \pi f}\right)\right] \quad (16).$$

This formula is exact and has a finite form, n_1 and n_2 being interpreted as in § 7.

The efficiency of Involute Teeth is as before

$$E = 1 - R$$

where R is given in (16).

13. A more convenient form of (16) is obtained by resorting to the logarithmic series:

$$\log(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3} - \frac{x^4}{4} + \&c.$$

Hence

$$\frac{n_1 - \pi f}{n_1 f} \log\left(1 + \frac{\pi f}{n_1 - \pi f}\right) =$$

$$\frac{\pi}{n_1} - \frac{\pi^2 f}{2n_1(n_1 - \pi f)} + \frac{\pi^3 f^2}{3n_1(n_1 - \pi f)^2} - \&c.$$

$$\frac{n_1 + \pi f}{n_1 f} \log\left(1 + \frac{\pi f}{n_1 + \pi f}\right) =$$

$$\frac{\pi}{n_1} - \frac{\pi^2 f}{2n_1(n_1 + \pi f)} + \frac{\pi^3 f^2}{3n_1(n_1 + \pi f)^2} - \&c.$$

Substituting these values in (16) we get

$$R = \left(\frac{1}{n_1} + \frac{1}{n_2}\right)\frac{\pi f}{2}\left[\frac{n_1^2}{n_1^2 - \pi^2 f^2} - \frac{2n_1 \pi f}{3} \cdot \frac{n_1^2 + \pi^2 f^2}{(n_1^2 - \pi^2 f^2)^2} + \right.$$

$$\left. \frac{\pi^2 f^2}{2} \cdot \frac{n^4 + 3n_1^2 \pi^2 f^2}{(n_1^2 - \pi^2 f^2)^3} - \&c.\right] \quad (17).$$

14. Formula (17) may be still more reduced by performing the divisions indicated by the fractions in the brackets.

Thus $$\frac{n_1^2}{n_1^2 - \pi^2 f^2} = 1 + \frac{\pi^2 f^2}{n_1^2} + \frac{\pi^4 f^4}{n_1^4} + \&c.$$

$$\frac{n_1^2 + \pi^2 f^2}{(n_1^2 - \pi^2 f^2)^2} = \frac{1}{n_1^2} + \frac{3\pi^2 f^2}{n_1^4} + \&c.$$

$$\frac{n_1^4 + 3n_1^2\pi^2 f^2}{(n_1^2 - \pi^2 f^2)^3} = \frac{1}{n_1^2} + \frac{6\pi^2 f^2}{n_1^4} + \&c.$$

These values put in (17) give

$$R = \left(\frac{1}{n_1} + \frac{1}{n^2}\right)\frac{\pi f}{2}\left[1 - \frac{2\pi f}{3n_1} + \frac{3\pi^2 f^2}{2n_1^2} - \frac{2\pi^3 f^3}{n_1^3} + \&c.\right] \quad (18).$$

This gives the ratio of energy lost to energy exerted on Involute Teeth.

15. A comparison of the efficiencies of the two kinds of teeth is easily made by means of (12) and (18). The agreement is surprising. For two terms they are identical. For the purpose of seeing which is the greater, the third and fourth and fifth terms in (12) should be compared with the third in (18), for the terms containing higher powers of f in the numerator, and of n_1 in the denominator, may well be omitted. That is to say, how does $\frac{1}{6e^2} + \frac{f^2}{2e^2} + \frac{f^2}{2}$ for epicycloidal teeth, compare with $\frac{3f^2}{2}$ for involute teeth? If e is as large as possible, that is unity, we have $\frac{1}{6} + f^2$ for the first; and the second expression, $\frac{3}{2}f^2$ can equal it only on the supposition that $f^2 = \frac{1}{3} = 0.33$ or $f = 0.575$, which is a rather violent supposition. For common values of e and f, it is evident that the loss is greater for epicycloidal teeth, hence their efficiency is less; but the difference is too small to be of practical value.

Issued May 10, 1898.

DISCUSSION OF SERIES DYNAMO-ELECTRIC MACHINES.*

CARL KINSLEY.

I.

FROM FUNDAMENTAL CONSIDERATIONS:

a. The dynamo and motor surfaces are obtained.
b. The use of a generator driving a single motor running at constant speed under all loads is considered.

II.

FROM TESTS OF PARTICULAR MACHINES:

a. The dynamo and motor surfaces are gotten.
b. A method of getting instantaneous values of engine speed is established.
c. The operation of the motor is predetermined.

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* Presented in abstract before The Academy of Science of St. Louis, April 18, 1898.

I a.

Dynamo and Motor Surfaces.

The relations between the current, electromotive force and speed of dynamo-electric machines have been extensively studied ever since Dr. John Hopkinson* first examined the subject. M. Marcel Deprez † called the relation between the current and electromotive force when the speed was constant the characteristic of the machine. This name has been universally adopted. In this paper I will call the relation

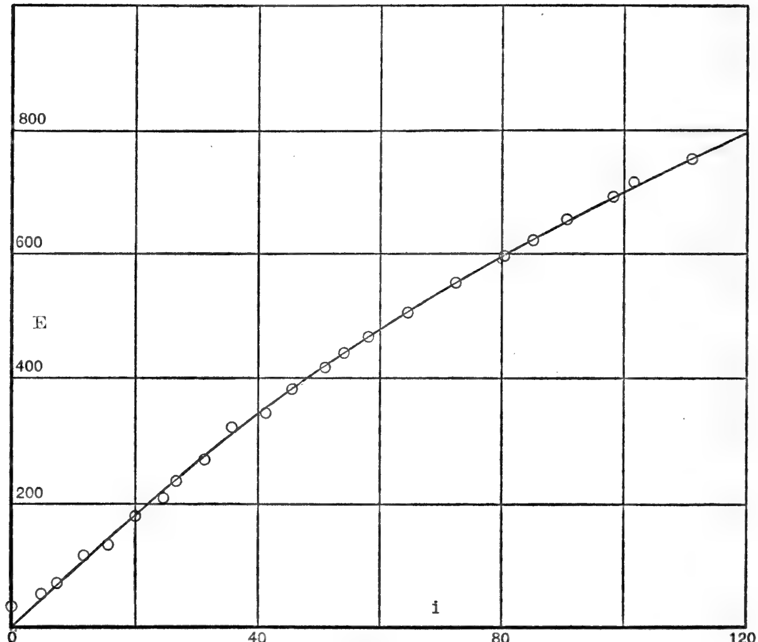

Fig. 1

Internal Characteristic of Shunt Dynamos with Scales Changed.

between the three variables — current, electromotive force, and speed — the *characteristic surface* of the machine and the algebraic expression the *characteristic equation*.

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* Proc. Inst. Mech. Eng., p. 238. 1879.

† La Lumiere Electrique Dec. 3, 1881.

An examination of the characteristic of a dynamo, such as is given in fig. 1,* suggests that it may be a part of an hyperbola. (See also figs. 10 and 12.) Since the total induced electromotive-force is directly proportional to the speed when the current is constant, see figs. 9 and 11, we can unite these two conditions and obtain the characteristic surface of the series dynamo. In fact fig. 2 shows how the surface may be built up by connecting together a large number of the straight lines.

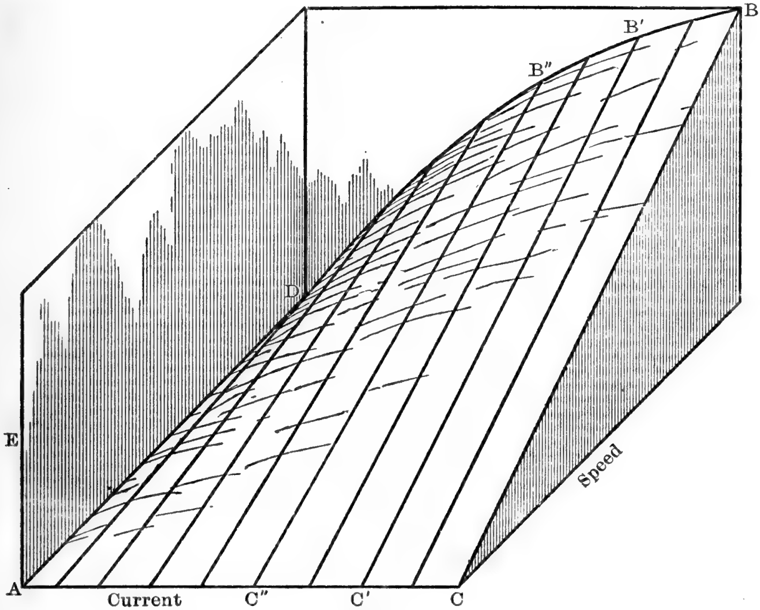

Fig. 2
Series Dynamo Surface.

The line DB of fig. 2 is the characteristic of the machine at the speed AD. The lines CB, C′B′, etc., give the relations between E. M. F. and speed when the current has the constant values AC, AC′, etc. In this way the characteristic surface can be defined by the actual tests of the dynamo or motor.

* The curve shown is the same that was gotten from a Weston dynamo using the armature and fields in series. The scales have been changed for convenience.

If we can obtain an algebraic expression for this relation it will be possible to use the surface for many engineering purposes.

Dr. O. Frölich * started this investigation which can be profitably extended † to include many vexing problems.

The actual tests of dynamo and motor are given in the second part of this paper, but in this part a more simple condition is used to illustrate the method of examination.

Symbols.

e = electro-motive force impressed on the terminals.
E = total electro-motive force induced in the armature of the dynamo.
E_a = counter e. m. f. of the motor.
i = current.
n_1 = rev. pr. sec.
n = rev. pr. min. of the dynamo.
n' = rev. pr. min. of the motor.
H = magnetic density in the air gap.
μ_1 = max. value of permeability of the magnetic circuit.
σ = a factor depending upon the saturation.
A = area of the armature coil.
S = number of turns of wire on the magnates.
G = a constant depending upon the design of the machine.
R = total resistance of the circuit.
r = resistance between the terminals.

The total induced e. m. f. in the armature conductors depends directly on the speed and strength of the field through which the conductors pass — see eq. (1) p. 111.

The strength of the field in the air gap has a very complex relation to the other conditions of the magnetic circuit. This

* Berl. Berichte 962, 1880. Electrotechinsche Zeitschrift, ii, 134, 170, 1881, vi, 128, 1885; ix Nov. 1888.

† Prof. F. E. Nipher a good many years ago noticed the fact that the empirical equation of Frölich was that of an hyperbolic paraboloid. For some years he taught his students that this surface and its elements could be profitably used in examining the operation of dynamo-electric machines. This surface is therefore explained in Ia of this paper so that the methods suggested in Ia may be employed in the remainder of the paper.

can be expressed by means of the empirical equation given on page 111 eq. (2). This is justified by the experimental work given in II. It will be found to be true in all the many cases where the demagnetizing effect of the armature remains nearly constant or relatively small. This condition is found when the brushes remain stationary and the change in armature current changes but slightly the resultant field.

The data given first were gotten from a machine which had an exceedingly strong field. Machines with relatively weaker fields have the constants a and b (p. 111) apply to only small parts of the characteristic, see p. 127.

The dynamo and motor can be considered together since in the case of the dynamo

$$e = E - ri$$

and for the motor

$$e = E_a + ri$$

the surface in which only the total induced electromotive forces are considered being similar in all respects.

Assume for the present that the following equations are true.

$$E = 4An_1H \tag{1}$$

$$H = GSi \frac{\mu_1}{1 + \sigma Si} \tag{2}$$

From (2) it is seen that an increase of the magnetizing ampere turns will decrease the permeability of the circuit.

from (2) and (1)

$$E = 4A \frac{n}{60} GSi \frac{\mu_1}{1 + \sigma Si} \tag{3}$$

from our assumptions we can let

$$\frac{4AGS\mu_1}{60} = \text{a constant} = a$$

also

$$S\sigma = \text{a constant} = b$$

then (3) will become

(4) $$E = \frac{ani}{1 + bi}$$

The important point to determine now is whether or not our assumptions in regard to the constants σ, G and μ_1 are realized in actual practice.

Equation (4) can be arranged as follows

(5) $$\frac{E}{ni} + \frac{Eb}{n} = a$$

Let $\frac{E}{ni} = x$ and $\frac{E}{n} = y$ then

$$x + yb = a$$

is recognized as the equation of a straight line.

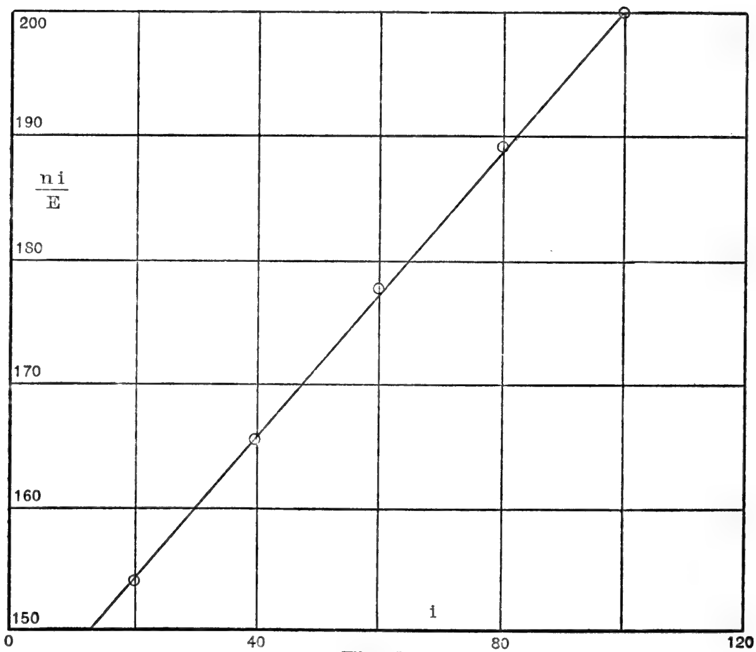

Fig. 3

Series Dynamo Constants Determined when the Speed does not Change.

In the case of any series machine if x and y be plotted and found to give a straight line then it is true for that machine that a and b are constants according to the assumptions.

Equation (4) can also be arranged

$$\frac{1}{a} + \frac{bi}{a} = \frac{ni}{E} \tag{6}$$

Here as in (5) if a plot of i and $\frac{ni}{E}$ give a straight line then a and b must be constant.

Fig. 3 gives this relation for five points taken from the characteristic. See also fig. 13, fig. 15, and p. (127).

a and b may be gotten by solving the following equations:

$$\frac{1}{a} + i\frac{b}{a} = \frac{ni}{E}$$

$$\frac{1}{a} + 100\frac{b}{a} = 200$$

$$\frac{1}{a} + 20\frac{b}{a} = 154.4$$

See fig. 3.

$$a = 0.007$$
$$b = 0.004$$

Equation (4) becomes

$$E = \frac{0.007\ ni}{1 + 0.004\ i} \tag{7}$$

Equation (7) is the *characteristic* equation of this series dynamo.

The surface of which that is the equation is the *characteristic surface* of the series dynamo.

Dynamo Surface.

If we impose the condition that n = constant = 1400

$$E = \frac{9.8\ i}{1 + 0.004\ i} \tag{8}$$

See fig. 5, DB.

This is the equation of the characteristic of the dynamo. A curve drawn on fig. 1 from eq. (8) will give a curve coinciding with the characteristic of the machine which would be drawn from the data throughout all working conditions and would depart from it only for extremely low currents.

In the preceding it has been shown that in this particular case the characteristic equation of the machine determines the characteristic of the machine at constant speed.

This has been done for many machines for varying conditions such as

$$R = \text{a constant},$$
$$n = \text{a constant},$$
$$i = \text{a constant, etc.}$$

and the experimental results gotten very accurately coincided with the results expected from the characteristic equation—eq. (4). See II.

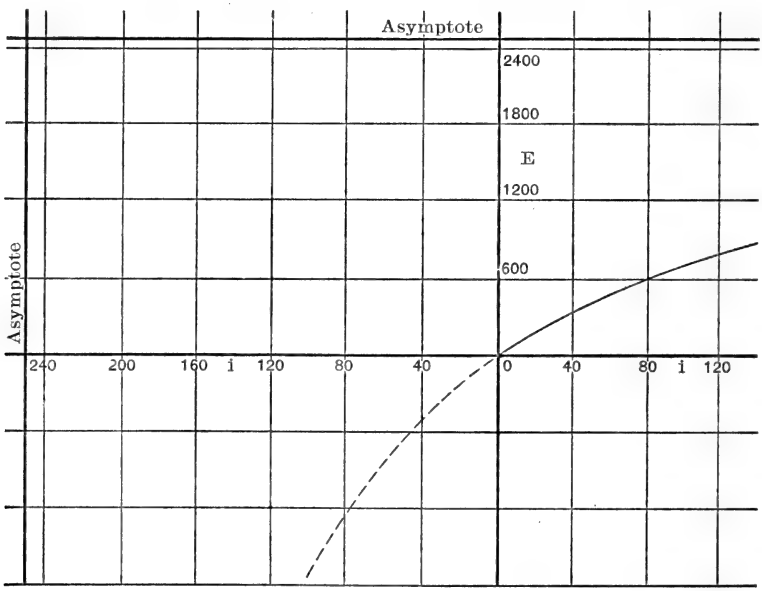

Fig. 4

Series Dynamo Characteristic. Speed Equals 1400 rev. pr. min.

The following four pages will be devoted to a discussion of the characteristic equation. The results obtained can be compared with those gotten from any available machine.

(4) $$E = \frac{ani}{1 + bi}$$

Impose the condition that n = a constant = 1400

It has already been found that

$$a = 0.007 \quad \text{and}$$
$$b = 0.004$$

(8) $$E = \frac{9.8\ i}{1 + 0.004\ i}$$

This is the equation of an hyperbolic curve having the asymptotes

$$E = \frac{an}{b} = 2450 \qquad \text{when } i = \infty$$

and

$$i = \frac{1}{b} = -250 \qquad \text{when } E = \infty$$

See fig. 4.

The characteristic at a constant speed of n = 1000 has the equation

(9) $$E = \frac{7.0\ i}{1 + 0.004\ i}$$

and can be plotted without difficulty.

See fig. 6 JJ′.

If we impose the condition that i = a constant = 120

$$E\ (1 + bi) = ani \quad \text{from (4)}$$

(10) $$E = 0.567\ n$$

See fig. 5 BC

when the constants are substituted.

Equations (9) and (10) are the equations of the *lines of intersection* of planes, parallel to the co-ordinate planes, with the *characteristic surface*.

These planes will limit the solid and bound the surface within the limits used in this particular case.

This is shown and the method of plotting with the use of three axes is plainly evident from fig. 5.

The surface used is thus bounded by the lines AD, DB, BC and CA.

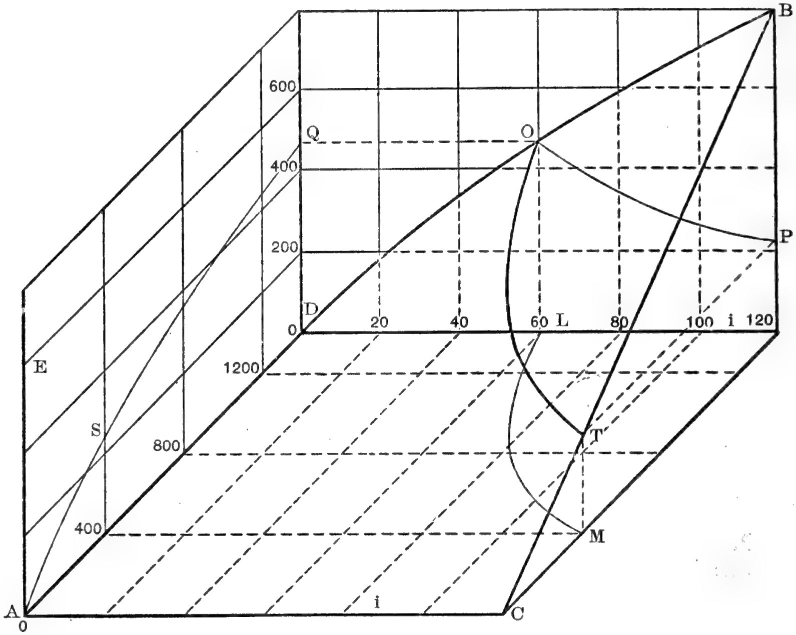

Fig. 5

Series Dynamo Surface. The Condition of Power Equal to a Constant is Shown.

If we wish the relation between the variables for the condition of constant power it may be gotten as follows:—

$$\text{Let } Ei = \text{a constant} = d = 28400$$

(14) $$Ei = 28400$$

See fig. 5 OP.

from equations (4) and (14)

$$n = \frac{d}{ai^2} + \frac{db}{ai}$$

(15) $$n = \frac{4{,}060{,}000}{i^2} + \frac{16240}{i}$$

See fig. 5 LM

$$n = \frac{E^2}{ad} + \frac{bE}{a}$$

(16) $$n = 0.00505\,E^2 + 0.572\,E$$

See fig. 5 QS.

Equations (14), (15) and (16) are the equations of the projections upon the co-ordinate planes of a line on the surface. See fig. 5 OT.

These curves are decidedly interesting ones, but they will not be discussed at present.

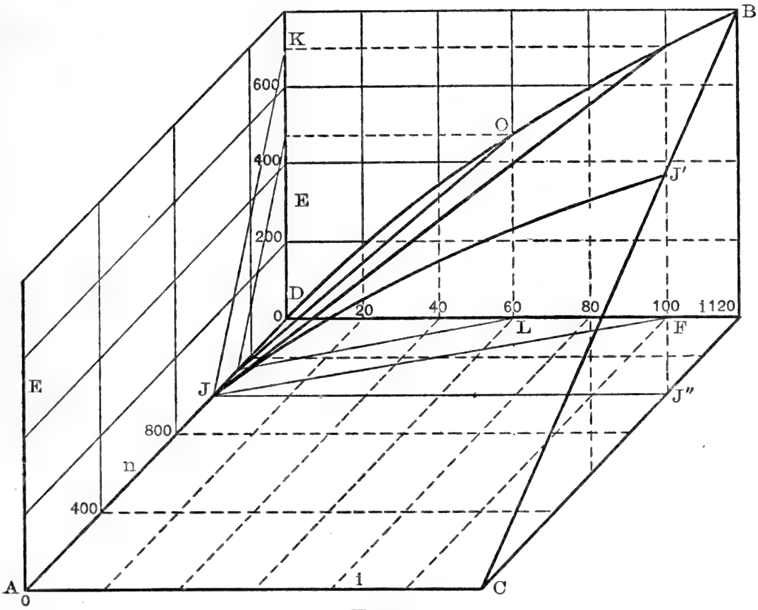

Fig. 6

Series Dynamo Surface. Resistance Equal to 7 Ohms and Resistance Equal to 7.9 Ohms.

It is important to know how speed, electromotive-force, and current will vary with reference to each other if the circuit is kept constant.

Then R = a constant. Let R = 7

(11) $$E = Ri = 7\,i$$

from (4) and (11)

$$n = \frac{R}{a} + \frac{bRi}{a}$$

(12) $$n = 1000 + 4.0\ i$$

See fig. 6 JF.

$$n = \frac{R}{a} + \frac{b}{a}\ E$$

(13) $$n = 1000 + 0.572\ E$$

See fig. 6 JK.

Equations (11), (12) and (13) are the equations of the projections upon the co-ordinate planes of a line on the surface which gives the simultaneous variation of E, i and n.

It is instructive to note that projections on the En plane for different resistances are parallel, while the projections on the ni plane are not parallel, but vary with R as is shown by the co-efficient of i containing R in one case and not in the other.

It will be observed that from equations (12) and (13) the constants of the equation for the surface can be easily gotten, should it be experimentally easier to vary n than R. In the laboratory it is generally easy to vary R but frequently in practice n can be varied by throttling the steam, where a change of R is impracticable. See figs. 14 and 16.

By the means outlined above it is a simple matter to foretell the result of any change in the conditions of operation.

Ib.

Series Dynamo and Series Motor.

The foregoing discussion of the series dynamo characteristic surface, as has been pointed out, applies equally to the series motor, when E_a is plotted instead of the E of the dynamo.

As has been shown the counter electromotive-force — E_a — of the motor is analogous to the total electromotive-force of the dynamo.

It is occasionally desirable in actual practice to operate one series motor as the only load of a series dynamo. Usually then it is essential that the motor regulate for constant speed with widely varying loads.

If it was desirable to run a motor whose characteristic was as given by DU of fig. 8, — data, p. 121 the necessary conditions could be gotten as follows:—

The motor characteristic is drawn on the Ei plane of fig. 8, without reference to the speed axis.

In this case the motor constants are

$$a'=0.0067$$
$$b'=0.0066$$

determined when the motor speed (n') was 1000 rev. pr. min.

The motor characteristic equation is therefore

(17) $$E_a = \frac{a'n'i'}{1+b'i}$$ and since

(18) $$E = E_a + Ri = \frac{ani}{1+bi} = \frac{a'n'i}{1+b'i} + Ri$$

This can be arranged

(18) $$\frac{a}{1+bi} = \frac{n'}{n}\frac{a'}{1+b'i} + \frac{R}{n}$$

If the desired conditions that n', n, and R be constant, for varying loads and consequently varying current, are possible with the above dynamo and motor a plot of

$$\frac{a}{1+bi} = x$$ and

$$\frac{a'}{1+bi} = y$$

will give a straight line.

Through what range of current the above conditions are possible can be easily seen from the plot of x and y. See fig. 7.

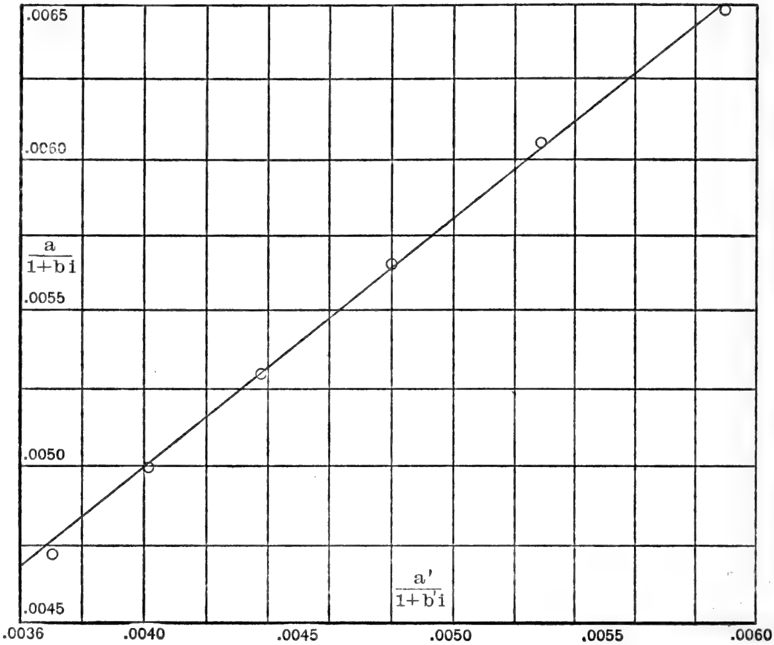

Fig. 7

Design of Series Power Circuit for Constant Speed of Machines.

Computed Data from Surface Constants.

E_1 = Total induced e. m. f. of dynamo at 1250 rev. pr. min.
E = Total induced e. m. f. of dynamo at 1400 rev. pr. min.
E_a = Total induced e. m. f. of motor at 1000 rev. pr. min.

$$A = \frac{a}{1 + bi} = \frac{.0070}{1 + .004\,i}$$

$$B = \frac{a'}{1 + b'i} = \frac{.0067}{1 + .0066\,i}$$

% = percentage variation of motive speed when dynamo speed is 1250 r. p. m. and R = 2.25

i	E	E_a	E_1	$E_a + Ri$	*A*	*B*	%
20	181.5	118.0	167.0	163.0	.00648	.00590	+2.5
40	338.0	212.0	302.0	302.0	.00605	.00530	0.0
60	474.0	288.0	423.0	423.0	.00565	.00480	0.0
80	594.0	351.0	530.0	531.0	.00530	.00439	—0.2
100	700.0	404.0	625.0	629.0	.00500	.00404	—0.5
120	795.0	447.0	710.0	717.0	.00473	.00372	—1.0

The values of $\frac{a}{1+bi}$ and $\frac{a'}{1+b'i}$ given on page 121 are plotted. See fig. 7.

As is seen a straight line averages the points very fairly from i = 110 to i = 30.

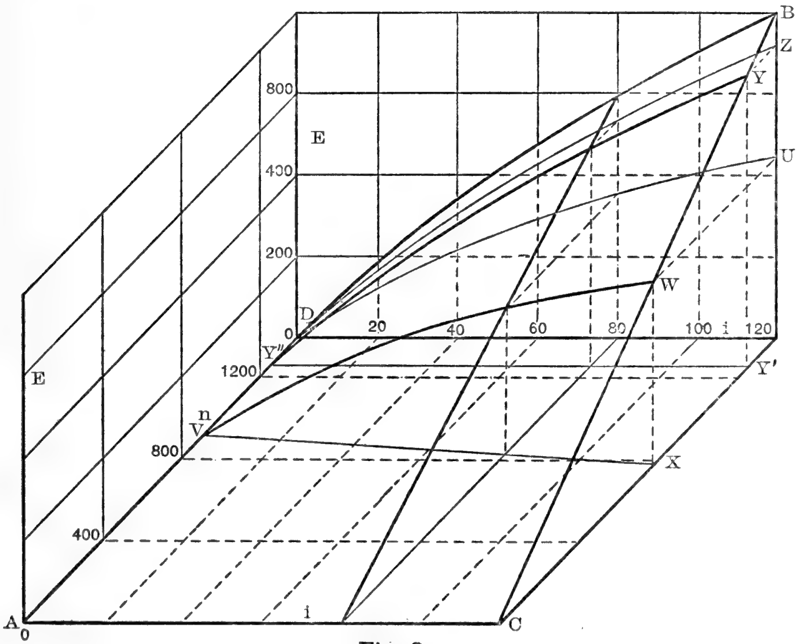

Fig. 8

Series Dynamo Surface and Motor Characteristic.
Design of Power Circuit.

From the line we find that

(20) $$\frac{n'}{n} = .80$$ (21) $$\frac{R}{n} = 0.00179$$

If it is desired that (n′) the speed of the motor be 1000 rev. pr. min. then

$$n = \frac{1000}{.8} = 1250 \quad \text{and}$$

$$R = 2.25 \qquad\qquad \text{from eqs. (20) and (21).}$$

Another value of n′ would require a different constant dynamo speed and a different line resistance.

If on the other hand n were fixed then n′ and R could be gotten from the above equations.

This condition can be very nicely illustrated, or a graphical solution can be gotten by the use of the characteristic surfaces.

From fig. 8. it is seen that the dynamo surface is ADBC. The motor characteristic at a constant speed of 1000 rev. pr. min. is the line DU.

Project the motor characteristic upon the dynamo surface and it gives us the line VW, upon the surface which projected upon the ni plane gives the line VX. This line is not necessarily straight. See fig. 19.

The line VX shows that the condition of constant speed of the motor would require varying speed of generator. If we add to the motor characteristic the e. m. f. = Ri, we would have as the result the line DZ which shows what the output of the dynamo must be to give the constant motor speed of 1000 r. p. m. when R = 2.25. DZ projected upon the surface gives us the conditions of operation of the dynamo in the line Y″Y.

This line projected upon the ni plane gives the line Y″Y′ which we see is a condition of a constant speed of 1250 rev. pr. min. of the dynamo for all currents. The line Y″ is thus the characteristic of the dynamo at a speed of 1250 r. p. m.

In the solution of the equations (20) and (21) if R had come out negative — see p. 136 — it would be impossible to use those two machines to regulate for constant speed with varying loads.

From our knowledge of the necessary resistance of the circuit for best regulation, it will be possible to most successfully design the circuit.

II a.

Series Dynamo and Motor Tests.

To what extent the foregoing discussion applies to the actual machine can be gotten from the following tests. Even if the equations did not apply the dynamo and motor surfaces could be established experimentally without any regard to their equations.

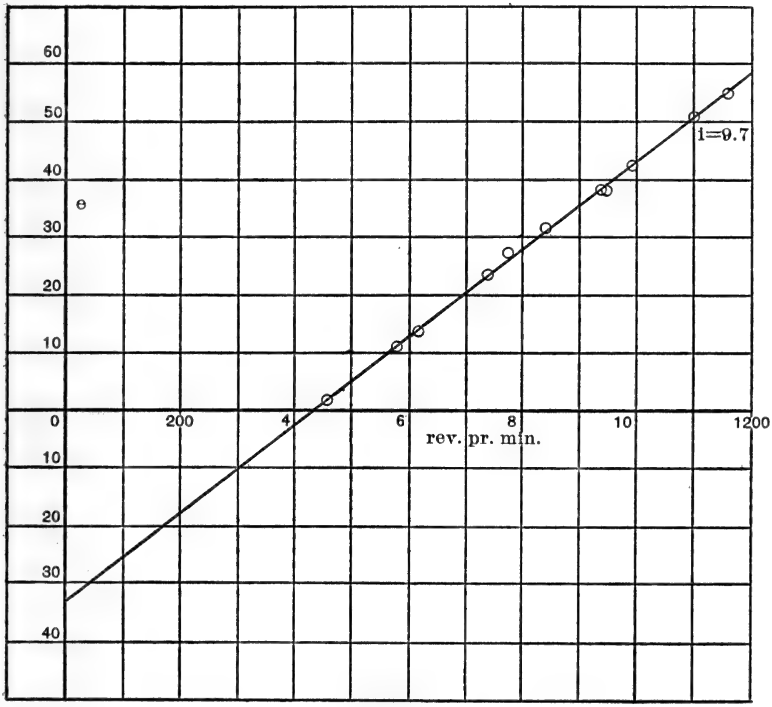

Fig. 9

Series Dynamo Test. Effect of Varying the Speed when the Resistance is Constant.

The relation between speed and electromotive force was determined for the condition of constant current by twelve series with currents varying between 9.7 and 2.0 amp. using a Wood series dynamo. The speed was gotten by an automatic chronograph record. The line determined with a constant current of 9.7 amp. is given in fig. 9. When the machine has been stopped (i. e., n = 0) the current is maintained by an impressed e. m. f. which is equal to the intercept of the line on the e. m. f. axis.*

The resistance of the machine is then this value divided by the current.

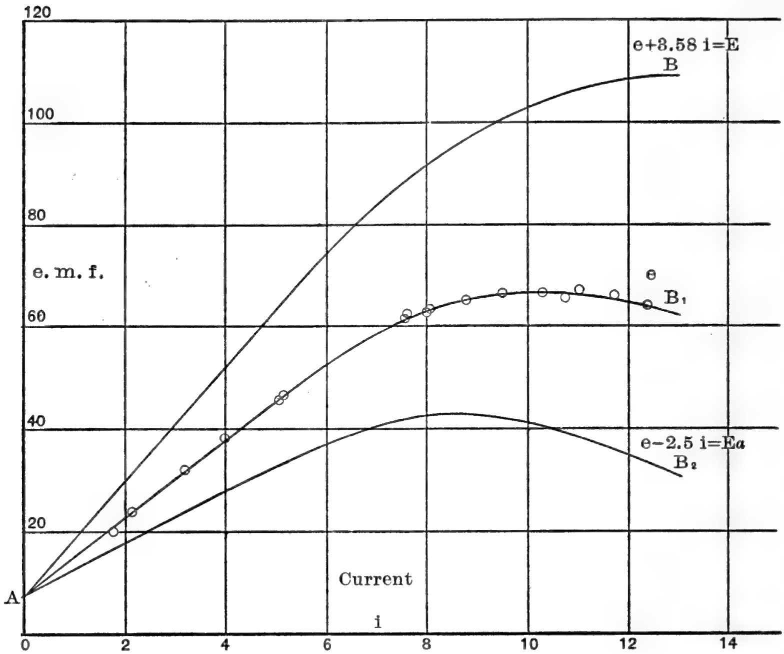

Fig. 10

Series Dynamo Test. E. M. Fs. Computed from those Observed.

From the observed line

$$e + ri = nc$$
$$55.3 + ri = 1159\ c$$
$$1.6 + ri = 454\ c$$

$$ri = 32.9 \quad \text{since}\ i = 9.7 \quad r = 3.39$$

* S. P. Thomson in "Dynamo-Electric Machinery, pp. 88 and 206, fifth edition, apparently disregards the fall of potential through the machine and so finds that the e. m. f. is *not* proportional to the speed. The correction is made by subtracting from the speed that gotten from the intercept on the n axis. He calls these rev. pr. min. the "*dead turns.*"

The resistance determined by the fall of potential method was	$r = 3.38$
In the twelve cases observed.	
The resistance computed from the line with the machine in operation was	$r = 3.135$
The resistance gotten by fall of potential method was	$r = 3.15$

The difference is accounted for by a better brush contact while the machine is running.

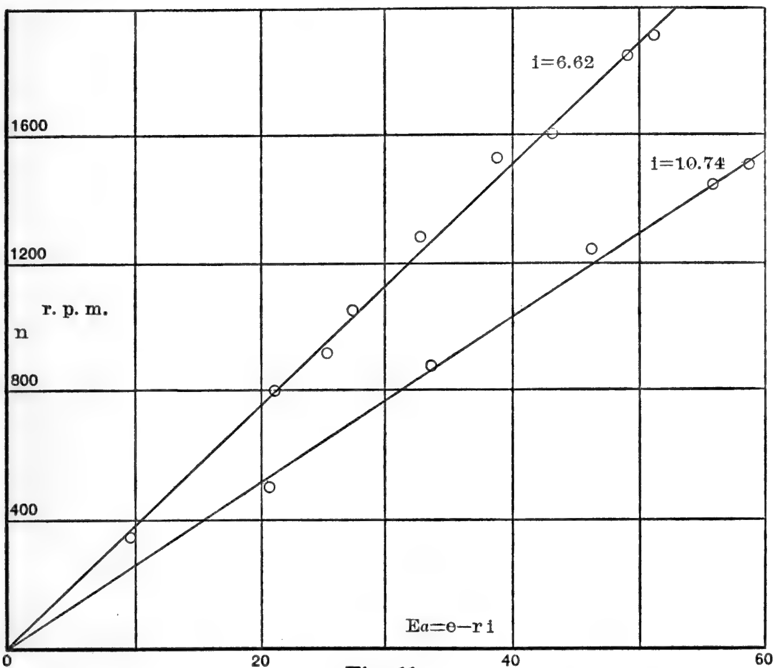

Fig. 11

Series Motor Test. Effect of Varying the Speed when the Resistance is Constant.

The fact that the lines are always straight shows that with widely varying speeds * the fall of potential through the machine remains a constant.

* S. P. Thomson, "Dynamo-Electric Machinery," p. 89, indorses the theory of "an apparent increase of resistance proportional to the speed," which was "first pointed out by Cabanellas in Comptes Rendus, Jan., 1882." In the above careful tests no evidence of a change of resistance can be found.

This is also true for the motor as is seen from fig. 11. The points do not lie as close to the line as in the case of the dynamo since a tachometer was used to determine the speeds. It will thus be evident that these straight lines will define the dynamo and motor surfaces. It will therefore be necessary to determine merely the characteristic of the machine.

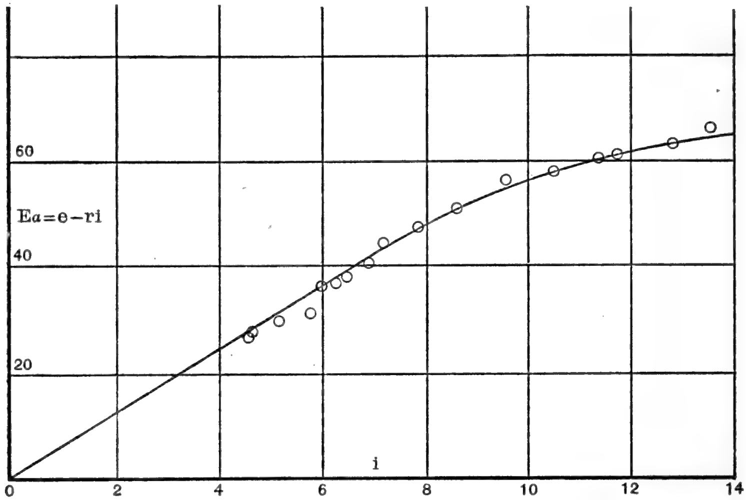

Fig 12

Series Motor Test. Characteristic Determined with Speed Equal to 1500.

The motor surface was also determined. See fig. 11 and fig. 12. The surface is shown in fig. 18 — the lines DB, C′B′ and C″B″ being the ones determined.

If we plot $\frac{ni'}{E}$ and i in order to get the constants of the surface in accordance with the method given on page 113, we have the lines ab, bc, and cd of fig. 13. The changes in the direction of the line seem to indicate the points of saturation of different parts of the magnetic circuit. This is also seen to be even more pronounced in the case of the motor in lines ef and fg of fig. 13.

For a limited range the constants of another machine were determined as is explained in connection with figs. 14, 15 and 16.*

* The internal characteristic of a 1500 K. W. power generator was also determined, and it was found that the relations could be expressed in the above way with complete accuracy.

Throughout the range of current covered by a straight line the constants of the characteristic equation are absolutely correct. When the current varies outside of that range then the constants change.

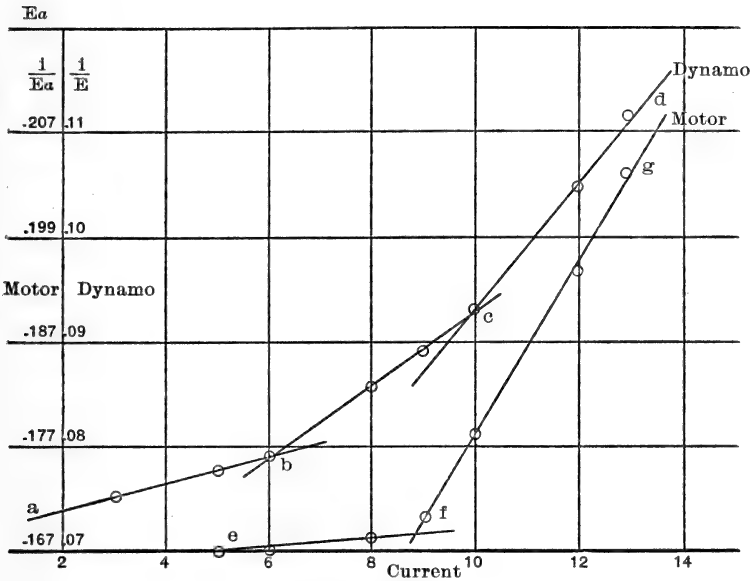

Fig. 13

Series Dynamo and Motor Tests. Determination of Constants when the Speed does not Change.

The departure of the points from the straight lines show with what degree of accuracy the equation assumed fulfills the conditions found in the actual machine.

It will therefore be possible in all machines to show by a surface the relations between E, i and n throughout the complete range of operation. Sometimes one and never more than three equations of the same form but with slightly different constants will give the algebraic relation between the variables under all conditions.*

* It has already been pointed out that the brushes must not be moved.

II b.

The Dynamo as a Speed Indicator.

In a great deal of experimental work it is essential that we determine the instantaneous values of the speed of the apparatus. This can be very easily done by using a dynamo electric machine attached to the revolving shaft.

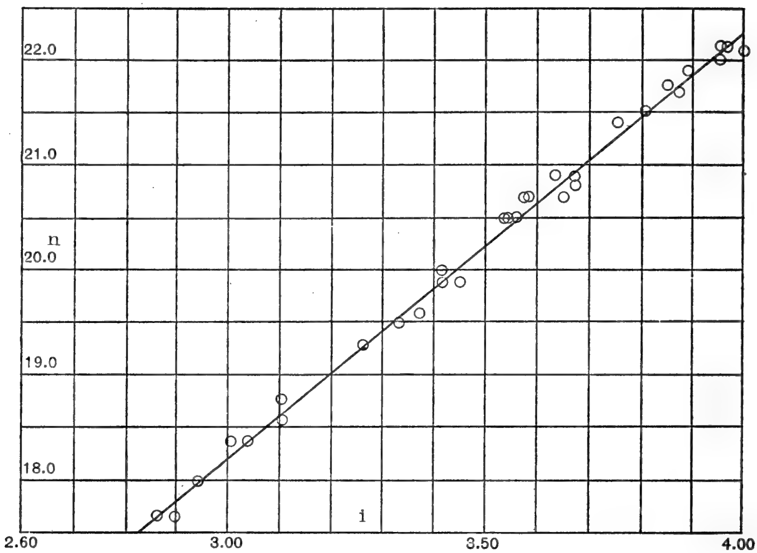

Fig. 14

Series Dynamo Test. Relation between the Current and Speed when the Resistance was Constant.

(1) If it is possible to use a separately excited dynamo with an electrostatic voltmeter connected to its brushes, then the speed is directly proportional to the potential shown by the voltmeter. Care must, of course, be taken to keep the exciting current constant.

Equation (1) p. 111 gives this relation.

$$E = 4\ AHn_1 = n_1 \text{ multiplied by a constant.}$$

(2) This can also be more simply obtained by using a self-excited series dynamo and either an ammeter in the circuit or a voltmeter across the brushes.

A very convenient machine for this purpose will be a shunt dynamo, with a very strong field, with the outside circuit left open and hence used as a series machine.

A small Wood dynamo used in this way gave the results shown in the figures. The speed was gotten automatically by means of a chronograph.

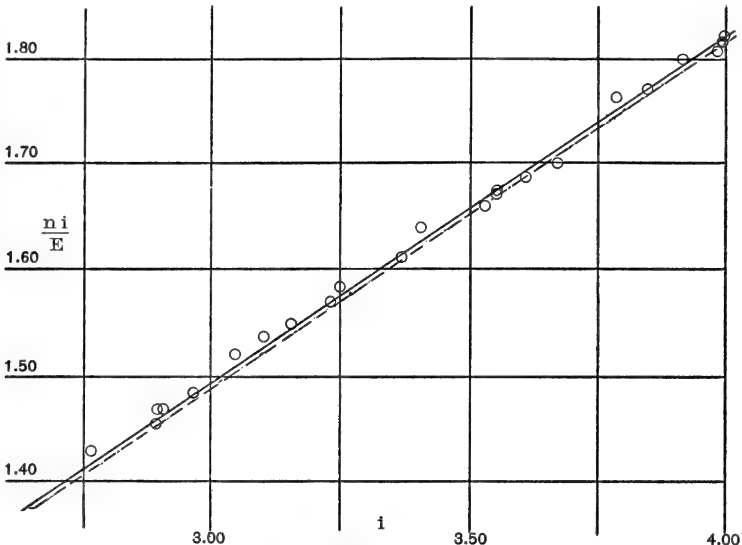

Fig 15

Series Dynamo Test. Computation of Constants when the Speed does not Change.

Figs. 14, 15, and 16 gave the data as taken. The excessively large scale makes the points appear somewhat scattered.

The equation of the line of fig. 14 is

$$\frac{R}{a} + \frac{b}{a} Ri = n_1 \quad \text{see p. 118}$$

When R = a constant = 12.23 ohms.

$$\frac{R}{a} + 2.935\ R \frac{b}{a} = 18.00.$$

$$\frac{R}{a} + 3.935\ R \frac{b}{a} = 22.00$$

from fig. 14

$$a = 1.945 \qquad b = 0.635$$

The equation of the line of fig. 15 is

$$\frac{1}{b} + i = \frac{n_1 i}{E} \frac{a}{b}$$

See p. 111.

When n_1 = a constant = 22.2

$$\frac{1}{b} + 3.00 = 1.496 \frac{a}{b}$$

$$\frac{1}{b} + 4.00 = 1.821 \frac{a}{b}$$

from fig. 15.

$$a = 1.915 \qquad b = 0.622$$

These constants differ somewhat from those gotten with the condition of R = a constant.

The dotted line of fig. 15 is one whose constants are as determined in the other two cases. The percentage varia-

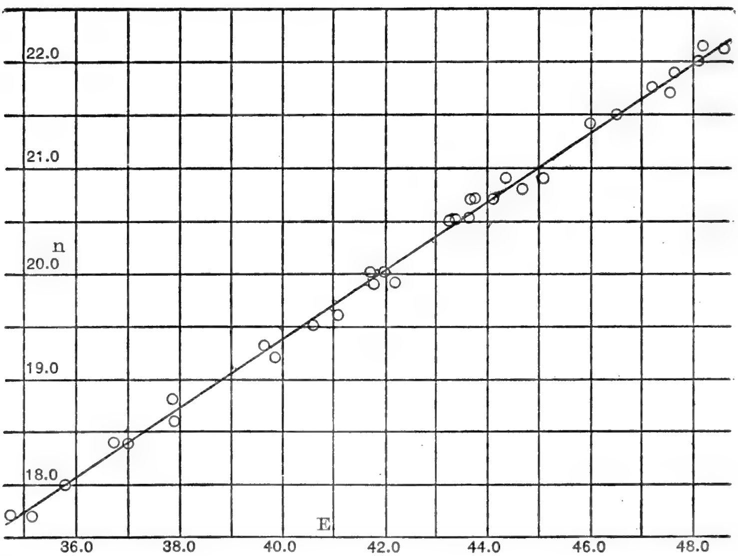

Fig. 16

Series Dynamo Test. Relation between the E. M. F. and Speed when the Resistance was Constant.

tion is found to be very small. If the constants *a* and *b* were determined with the condition of constant speed, and a line was then platted showing the relation between n_1 and i, the values of n_1 determined from the line, from readings of i, would differ from the true n_1 by not more than $\frac{1}{2}$%.

The equation of the line of fig. 16 is

$$\frac{R}{a} + \frac{b}{a} E = n_1$$ See p. 118.

When R = a constant = 12.23

$$\frac{R}{b} + 35.85 \frac{b}{a} = 18.00$$

$$\frac{R}{a} + 48.10 \frac{b}{a} = 22.00$$

from fig. 16.

$$a = 1.945 \qquad b = 0.635$$

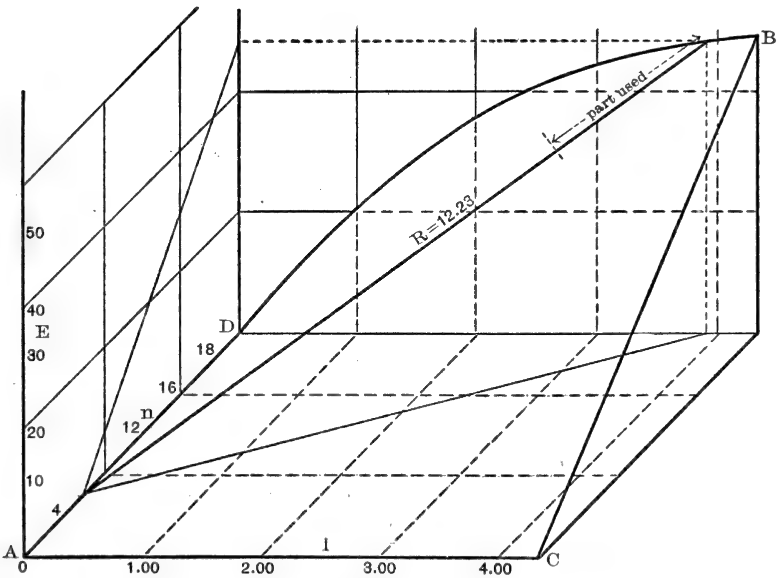

Fig. 17
Series Dynamo Surface. Effect of Varying the Speed when the Resistance is Constant.

It will thus be possible to determine this relation between n_1, i, and E by any one of the ways given with as great accuracy as the instrument may be read.

The equation of the surface is therefore

$$E = \frac{a n_1 i}{1 + b i}$$

See p. 112.

$$E = \frac{1.945\ n_1 i}{1 + 0.635\ i}$$

from figs. 14 and 16.

This surface is given on fig. 17. The element of the surface giving the condition of operation for constant resistance being indicated. The surface is explained in connection with figs. 5, 6, and 7.

It follows therefore from the computations just given that experimentally the relation between n_1, i, and E may be determined in the most convenient way and then this relation may be used to obtain instantaneous values of the speed of the apparatus to which this small machine is connected. This method has been used practically to determine the fluctuations of speed of an engine caused by sudden changes in its load.

II c.

The Predetermination of the Operation of a Single Series Motor as the only Load of a Series Generator.

This problem was first defined by Gisbert Kapp who sums up his observations in substance as follows — there can usually be found some speed and some resistance at which the motor will operate at constant speed for all loads.* He has been successful in obtaining the result desired in the installations he has made in England.

Eric Gerard, † an eminent French authority, indorses Kapp's solution of the problem.

C. E. L. Brown, while with the Oerlikon Engineering Co., of Switzerland, has also succeeded in operating motors installed

* "Electrical Transmission of Energy," 4th edition, p. 199.

† "Leçons sur L' Électricité," Tome second, p. 189.

in that way with no more than two per cent variation of speed.

Heer von Debrowolsky has done equally well in Germany I do not know of any such installation in the United States but Dr. Louis Bell* has followed Kapp in his solution of the problem. It would of course be more satisfactory to know whether or not the desired results could be obtained before installing and to know also just how to design the circuit.

The correctness of the method given under Ia for predetermining the operation of a series motor driven as the only load of a series dynamo was examined by means of a small four-pole Wagner Elect. Co.'s series motor and a two-pole Wood dynamo.

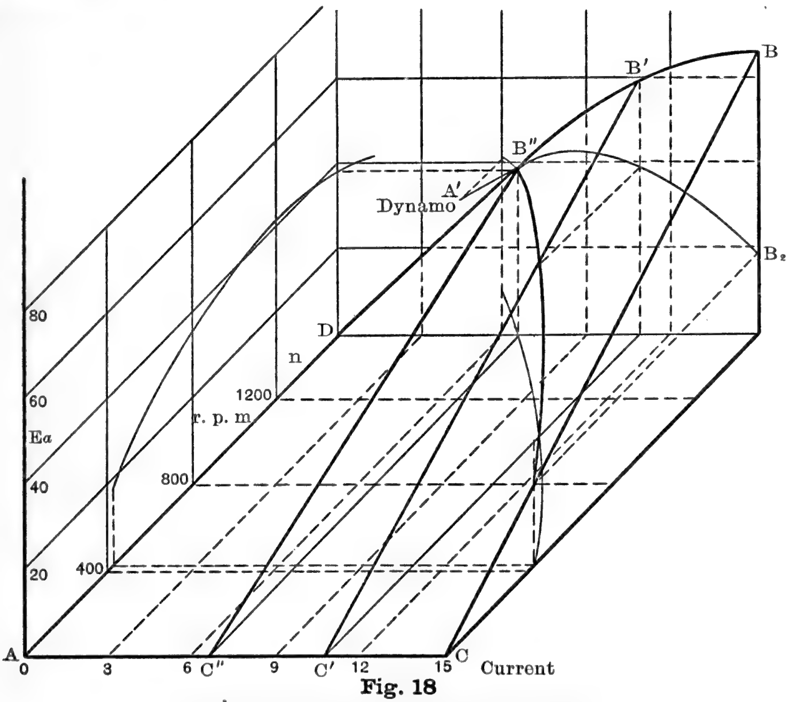

Fig. 18

Series Motor Surface and Dynamo Characteristic.
Predetermination of Motor Operation.

The characteristic surface of the motor was determined — figs. 11 and 12 give the data and fig. 18 is the surface — and

* "Electric Power Transmission," p. 86.

then independently the characteristic of the dynamo was obtained — fig. 10.

The line $A'B_2$ of figs. 10 and 18 will then give the counter e. m. f. that the motor must develop. This line was there-

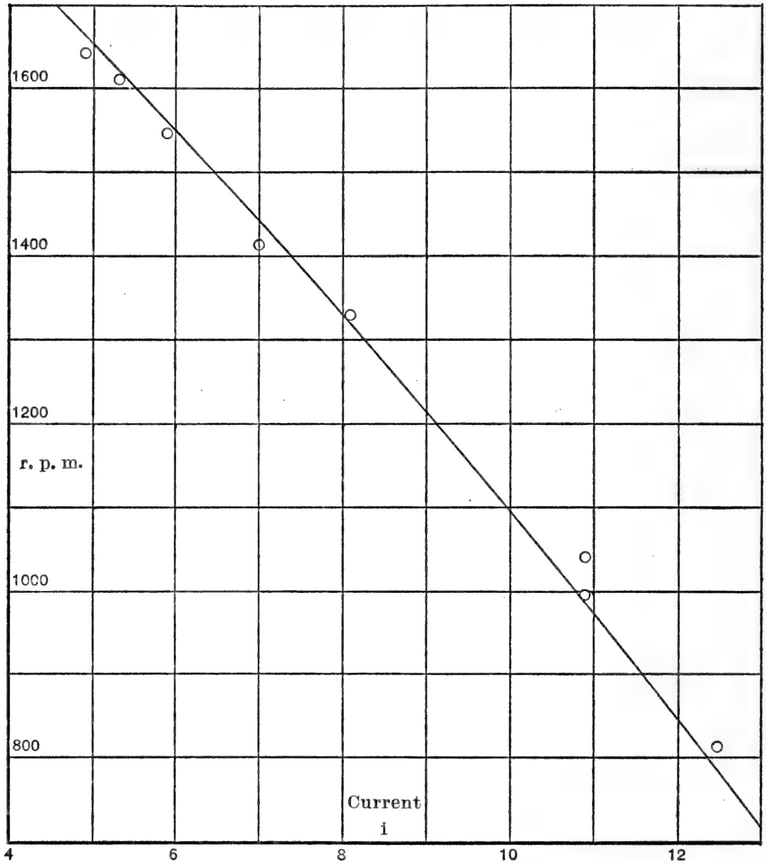

Fig. 19

Series Motor Test. Comparison of Observed and Computed Results.

fore projected onto the motor surface and the line on the surface was projected onto the ni plane giving the relation between speed and current to be expected when the motor was driven by the generator. This is seen in fig. 18 and enlarged is the full line of fig. 19. The motor was then driven by the generator and the indicated points of fig. 19 give the result.

Another and much more extensive test was made, but the speed of the dynamo was too erratic to allow a smooth curve to be drawn; the average difference between the computed and observed values of the motor speed was only 0.05%.

The resistance of the circuit that will cause the motor to operate at constant speed when the dynamo runs at 1300 r. p. m. can be determined by the method given on p. 119.

From the lines of fig. 13 we can get the constants for particular parts of the dynamo and motor surface and then can solve for the ratios $\frac{n'}{n}$ and $\frac{R}{n}$ for that range of current:

Dynamo

$$\frac{1}{a} + i\frac{b}{a} = \frac{i}{E}n$$

Speed constant = 1300

$$\frac{1}{a} + 10\frac{b}{a} = 0.093\ n$$

$$\frac{1}{a} + 13\frac{b}{a} = 0.111\ n$$

$$a = 0.0233$$
$$b = 0.1815$$

Motor

$$\frac{1}{a'} + i\frac{b'}{a'} = \frac{i}{E_a}n'$$

Speed constant = 1500

$$\frac{1}{a'} + 9\frac{b'}{a'} = 0.170\ n'$$

$$\frac{1}{a'} + 13\frac{b'}{a'} = 0.203\ n'$$

$$a' = 0.00702$$
$$b' = 0.0878$$

We have then within the same range of current

$$\frac{a'}{1+b'i}\frac{n'}{n} = \frac{a}{1+bi} - \frac{R}{n}$$

$$0.003745 \frac{n'}{n} = 0.00828 - \frac{R}{n} \quad \text{when } i = 10$$

$$0.003280 \frac{n'}{n} = 0.00695 - \frac{R}{n} \quad \text{when } i = 13$$

$$\frac{n'}{n} = 2.87 \qquad \frac{R}{n} = 0.00248$$

If we wish $n = 1300$

$$n_1 = 3730 \qquad R = -3.22$$

With these machines it will therefore never be possible to obtain a constant motor speed.

The very close coincidence between the computed and observed value of speed shows that this method of investigation can be accurately used.

Issued May 20, 1898.

THE NORMAL TO THE CONIC SECTION.

EDMUND A. ENGLER.

The determination by the usual methods of analytic geometry of the normals to a conic section from a point not on the curve involves the solution of a cubic or bi-quadratic equation by which the co-ordinates of the points at which the normals cross the curve may be found. This method, though of no special difficulty, is generally avoided on account of its tediousness, and in most elementary books the problem is considered solved when these equations are found. The graphical constructions given in this paper are accomplished without the algebraic solution of these equations and may prove to be a useful addition to courses in geometrical drawing, from which the solution of this problem is generally omitted. The analysis on which the constructions depend is based on well known principles of analytic geometry and is given in the most elementary and simple form.

THE NORMAL TO THE PARABOLA.

The equation of the parabola referred to its axis and the tangent at its vertex as axes of co-ordinates is, in the usual notation,

$$y^2 = 2px. \qquad (1)$$

The equation of the normal to the parabola is

$$py + xy_1 = py_1 + x_1y_1 \qquad (2)$$

in which x_1, y_1 are the co-ordinates of the point in which the normal crosses the curve.

If the normal is to be drawn through any point in the plane, P, whose co-ordinates are ξ, η, these co-ordinates must satisfy equation (2), so that

$$p\eta + \xi y_1 = p y_1 + x_1 y_1. \qquad (3)$$

The co-ordinates x_1, y_1 also satisfy equation (2).

If we now make x_1, y_1 variables, equation (3) becomes

$$p\eta + \xi y = py + xy. \qquad (4)$$

This equation is satisfied by the co-ordinates ξ, η and also by the co-ordinates x_1, y_1; and, therefore, represents a curve which passes through the given point P and through the intersections with the parabola of the normals through P.

Equation (4) represents an equilateral hyperbola. The equations of its asymptotes are

$$x = \xi - p \qquad (5)$$

and

$$y = 0. \qquad (6)$$

Equation (5) represents a straight line parallel to the axis of Y and at distance $\xi - p$ from it.

The distance from the point P to this asymptote is evidently

$$\xi - (\xi - p) \equiv p; \qquad (7)$$

that is, the asymptote is for all values of ξ at a distance p to the left of P.

The asymptote represented by equation (6) is the axis of X.

The auxiliary hyperbola can be readily constructed from the well known principle of constant areas, or perhaps more easily in one of the following ways:—

Since the secant intercepts equal distances between the curve and each asymptote of the hyperbola, we have only to draw any secant, as QPL (Fig. 1), and make LK equal to PQ; the locus of K will be the auxiliary hyperbola.

Again, it is evident from this principle that for any secant through P the triangles QRP and KML are equal; and that the bases on the axis of X of all such triangles as KML, no matter how the secant may be drawn, are of the same length, $ML = PR = p$. Therefore, to find a point on the hyperbola draw any secant through P; from the point where this secant intersects the axis of X lay off a distance p to the

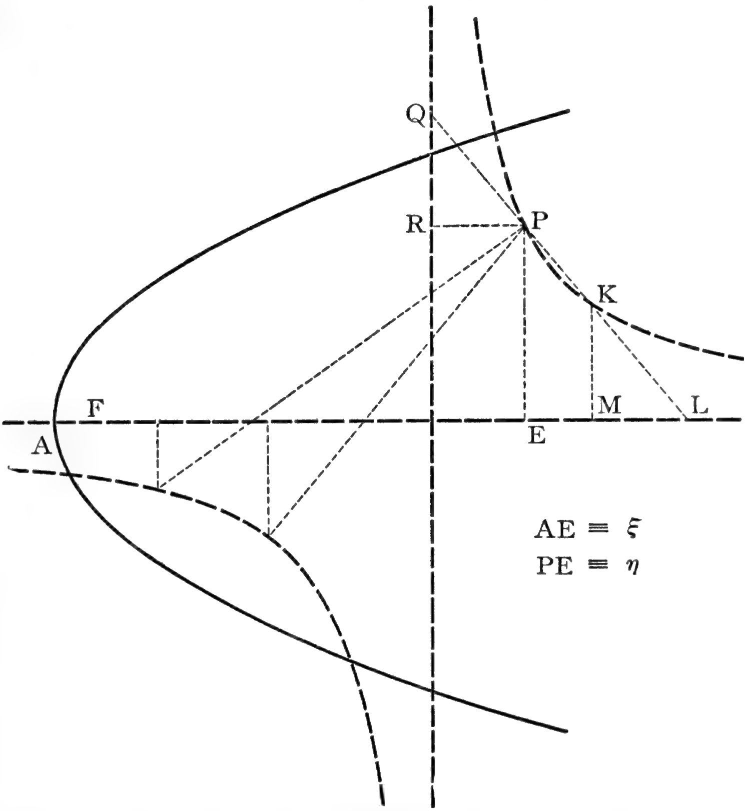

FIGURE 1.

left. At this point draw a line parallel to the axis of Y; the intersection of this line with the secant is a point on the hyperbola.

This hyperbola will intersect the given parabola in one, two, or three points according to the position of the point P in the plane. The actual construction of the hyperbola for any given case will give all the real normals possible for the given position of the point.

When the point P is so situated that only one branch of the hyperbola cuts the parabola, there will be only one normal.

When the point P is so situated that both branches of the hyperbola cut the parabola, there will be three normals.

When the point P is so situated that one branch of the hyperbola cuts the parabola while the other branch of the hyperbola is tangent to it, there will be two normals.

Both branches of the hyperbola cannot be tangent to the parabola, because the axis of X is one of the asymptotes of the hyperbola; for the same reason there must always be at least one real normal whatever the position of the point P.

The following analysis shows in what way the number of normals possible is dependent upon the position of the point in the plane:—

The equation of the tangent to the parabola may be written

$$y = \frac{p}{y'}x + \frac{p}{y'}x' \tag{8}$$

in which x', y' are the co-ordinates of the point of contact on the parabola.

The equation of the tangent to the hyperbola may be written

$$y = \frac{y'}{\xi - p - x'}x - \frac{y'}{\xi - p - x'}x' + y' \tag{9}$$

in which x', y' are the co-ordinates of the point of contact on the hyperbola.

If equations (8) and (9) are made to represent the same line, which signifies that the tangents to the two curves coincide, and if at the same time x', y' in (8) and (9) represent the same point, which means that the curves are tangent to each other at that point, we have as equations of condition,

$$\frac{p}{y'} = \frac{y'}{\xi - p - x'}, \tag{10}$$

$$\frac{p}{y'}x' = -\frac{y'}{\xi - p - x'}x' + y'; \tag{11}$$

from which for the co-ordinates of the point of contact,

$$x' = \frac{1}{3}(\xi - p), \tag{12}$$

$$y' = -\frac{3}{2} \cdot \frac{p\eta}{\xi - p}. \tag{13}$$

If these values are substituted in equation (1), we have

$$\eta^2 = \frac{8}{27} \cdot \frac{(\xi - p)^3}{p}. \tag{14}$$

This, if ξ, η are regarded as variables, is the equation of the evolute of the parabola, which is therefore the locus of the point P when the hyperbola and parabola are tangent to each other.

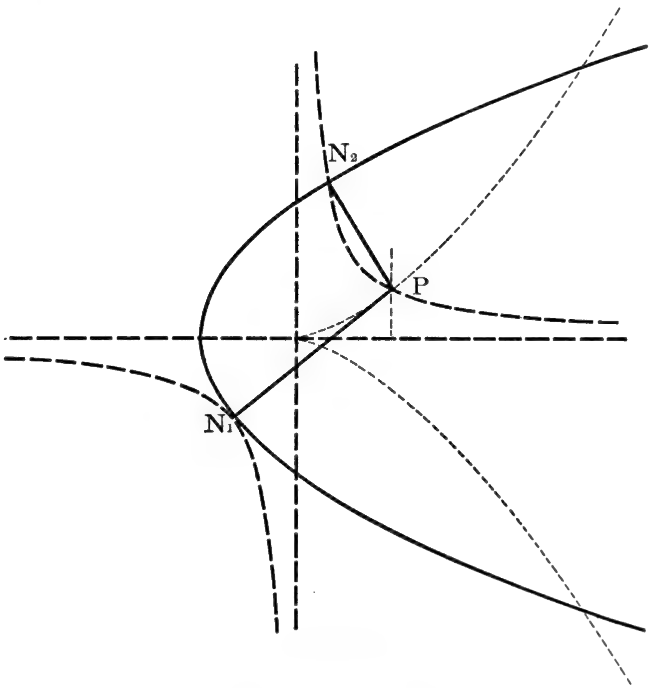

FIGURE 2.

Since the evolute of any curve is the envelope of its normals, the number of normals which can be drawn through a point on the evolute is always one greater than the number which can be drawn through a point on its concave side and one less than the number which can be drawn through a point on its convex side; that is to say, that for a point on the evolute, two of the theoretically possible normals coincide,

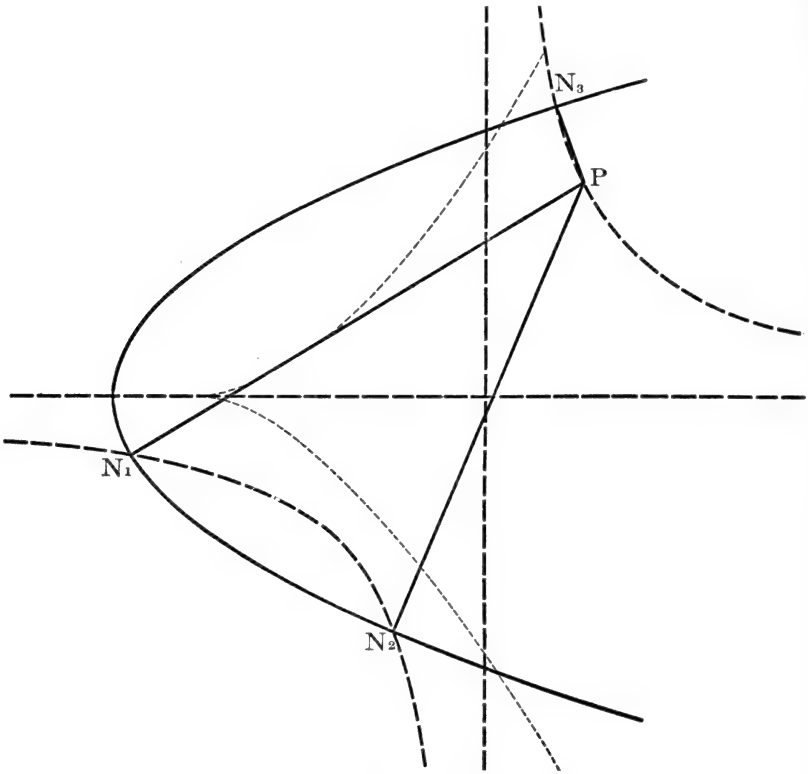

FIGURE 3.

and for a point on its concave side, two of them are imaginary, while for a point on its convex side, all of them are real.

From this property and by reference to the figures, it is apparent that for any point on the evolute (Fig. 2) one branch of the hyperbola is tangent to the parabola, while the other branch cuts it in a single point, and there are two normals, PN_1, PN_2; for any point in the plane on the convex side of the evolute (Fig. 3), both branches of the hyperbola cut the parabola, one in one point and the other in two points, and there are three normals, PN_1, PN_2, PN_3; and for any point in the plane on the concave side of the evolute (Fig. 4), only one branch of the hyperbola cuts the parabola and that in a single point, and there is but one normal, PN.

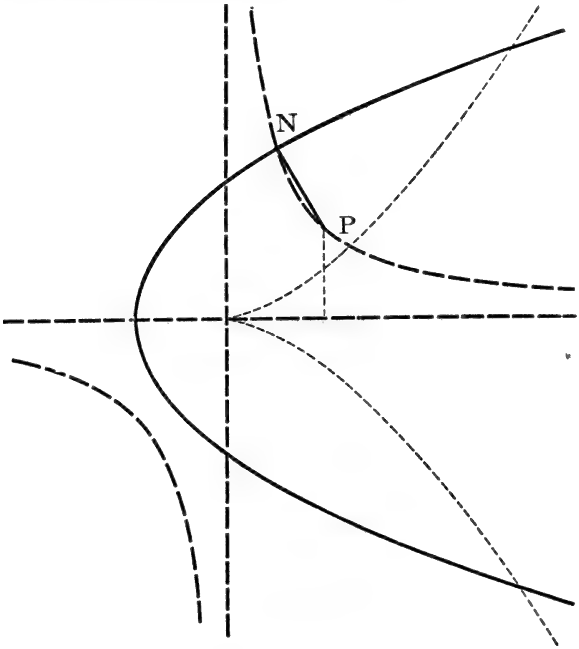

FIGURE 4.

Special Cases. 1. When the point P lies on the given parabola one of the normals through P coincides with the tangent to the hyperbola at that point and is found by joining with P a point on the axis of X at a distance p to the left of the foot of the ordinate through P; which is, in fact, the usual construction for this normal to the parabola based on the principle that the sub-normal is constant.

The other normals can be obtained by the construction already given.

2. When the point P lies on the axis of the parabola, the auxiliary hyperbola degenerates into its asymptotes. The intersections of these asymptotes with the parabola give the normals. It will be observed that when the point P is at the

cusp of the evolute, one of the asymptotes is tangent to the parabola at its vertex; this is a critical case for which the three real normals coincide.

The constructions for these cases can easily be supplied by the reader.

THE NORMAL TO THE ELLIPSE.

The equation of the ellipse referred to its rectangular axes as axes of co-ordinates is, in the usual notation,

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1. \qquad (15)$$

The equation of the normal to the ellipse is

$$a^2 x y_1 - b^2 y x_1 = (a^2 - b^2)\, x_1 y_1 \qquad (16)$$

in which x_1 y_1 are the co-ordinates of the point in which the normal crosses the curve.

If the normal is to be drawn through any point in the plane, P, whose co-ordinates are ξ, η, these co-ordinates must satisfy equation (16), so that

$$a^2 \xi y_1 - b^2 \eta x_1 = (a^2 - b^2)\, x_1 y_1. \qquad (17)$$

The co-ordinates x_1, y_1 also satisfy equation (16).

If now we make x_1, y_1 variables, equation (17) becomes

$$a^2 \xi y - b^2 \eta x = (a^2 - b^2)\, xy. \qquad (18)$$

This equation is satisfied by the co-ordinates ξ, η and also by the co-ordinates x_1, y_1, and, therefore, represents a curve which passes through the given point P and intersects the given ellipse at the intersection of the normals through P with the ellipse.

Equation (18) represents an equilateral hyperbola. The equations of its asymptotes are

$$x = + \frac{a^2}{a^2 - b^2}\xi \tag{19}$$

and

$$y = - \frac{b^2}{a^2 - b^2}\eta. \tag{20}$$

Equation (19) represents a straight line parallel to the axis of Y and at a distance $\frac{a^2}{a^2-b^2}\xi$ from it. As $\frac{a^2}{a^2-b^2}$ is necessarily positive, the expression $\frac{a^2}{a^2-b^2}\xi$ always has the same sign as ξ; therefore, the asymptote represented by equation (19) always lies on the same side of the axis of Y as the point P. And as $\frac{a^2}{a^2-b^2}$ is greater than unity, the point P lies between this asymptote and the axis of Y.

The distance from the point P to this asymptote is

$$\frac{a^2}{a^2 - b^2}\xi - \xi \equiv \frac{b^2}{a^2 - b^2}\xi. \tag{21}$$

Equation (20) represents a straight line parallel to the axis of X and at a distance $-\frac{b^2}{a^2-b^2}\eta$ from it.

As $\frac{b^2}{a^2-b^2}$ is necessarily positive, the expression $-\frac{b^2}{a^2-b^2}\eta$ always has the sign opposite to that of η; therefore, the axis of X lies between the point P and the asymptote represented by equation (20).

The construction of the auxiliary hyperbola for this case is similar to that already given for the parabola; but it will be observed that neither of the asymptotes coincides with one of the co-ordinate axes, and, therefore, a special construction to find each of them is necessary.

The asymptote parallel to the axis of Y will be found at a distance $\frac{b^2}{a^2-b^2}\xi$ beyond the point P (Fig. 5). To find it, join the end of the minor axis of the ellipse, B, with the focus, F. If we now let

$$\varphi \equiv \angle BFC, \quad \text{we have} \quad \frac{b}{(a^2-b^2)^{\frac{1}{2}}} = \tan\varphi$$

Through the center of the ellipse draw CD parallel to BF; then

$$DH = \xi \tan\varphi.$$

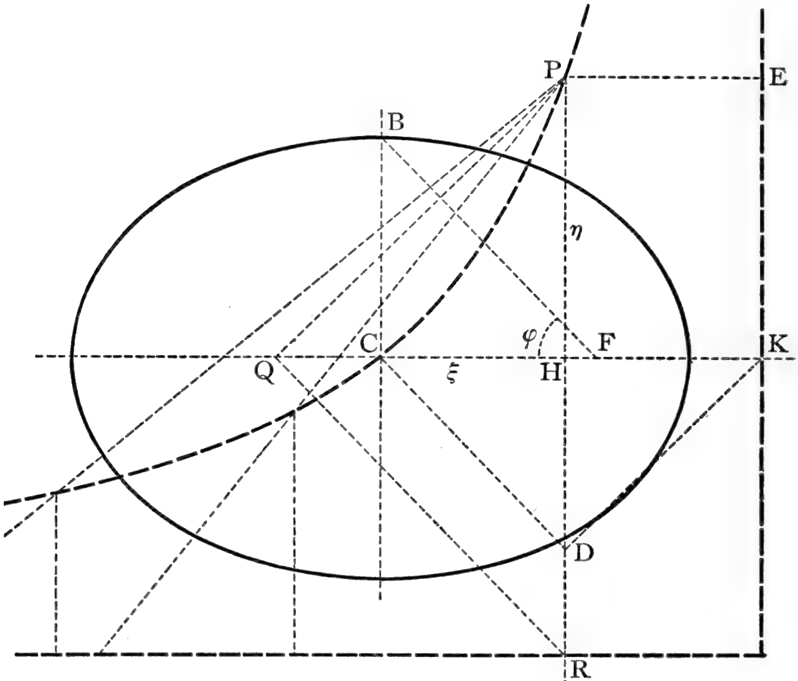

FIGURE 5.

Through D draw DK perpendicular to CD; then

$$HK = DH \cdot \tan\varphi = \xi \tan^2\varphi = \frac{b^2}{a^2-b^2}\xi; \quad (22)$$

therefore, (eq. 21) the line through K parallel to the axis of Y is this asymptote.

To find the asymptote parallel to the axis of X, through the point P draw PQ perpendicular to BF; then

$$QH = \eta \tan\varphi.$$

Through Q draw QR perpendicular to QP; then

$$HR = QH \cdot \tan \varphi = \eta \tan^2 \varphi = \frac{b^2}{a^2 - b^2}\eta; \qquad (23)$$

therefore, (eq. 20) the line through R parallel to the axis of X is this asymptote.

To find points on the curve the same construction can be employed as in the case of the parabola, but the constant base of the triangles on the asymptote parallel to the axis of X is in this case $\frac{b^2}{a^2 - b^2}\xi$ and, therefore, equal to the distance EP, in the figure.

This hyperbola will intersect the given ellipse in two, three or four points according to the position of the point P in the plane. The actual construction of the hyperbola for any given case will give all the real normals possible for the given position of the point.

When the point P is so situated that only one branch of the hyperbola cuts the ellipse there will be two normals.

When the point P is so situated that both branches of the hyperbola cut the ellipse there will be four normals.

When the point P is so situated that one branch of the hyperbola cuts the ellipse while the other branch of the hyperbola is tangent to it there will be three normals.

Both branches of the hyperbola cannot be tangent to the ellipse, since one branch of the hyperbola passes through the center of the ellipse, as is evident from equation (18); for the same reason there must always be at least two real normals, whatever the position of the point P.

The following analysis shows in what way the number of normals possible is dependent upon the position of the point in the plane: —

The equation of the tangent to the ellipse may be written

$$y = -\frac{b^2 x'}{a^2 y'}x + \frac{b^2}{y'} \qquad (24)$$

in which x', y' are the co-ordinates of the point of contact on the ellipse.

The equation of the tangent to the hyperbola is

$$y = \frac{a^2\xi y'^2}{b^2\eta x'^2}x - \frac{(a^2 - b^2)\, y'^2}{b^2\eta} \tag{25}$$

in which x', y' are the co-ordinates of the point of contact on the hyperbola.

If equations (24) and (25) are made to represent the same line, which signifies that the tangents to the two curves coin cide, and if, at the same time, x', y' in (24) and (25) represent the same point, which means that the curves are tangent to each other at that point, we have as equations of condition

$$-\frac{b^2x'}{a^2y'} = \frac{a^2\xi y'^2}{b^2\eta x'^2}, \tag{26}$$

$$\frac{b^2}{y'} = -\frac{(a^2 - b^2)\, y'^2}{b^2\eta}; \tag{27}$$

from which for the co-ordinates of the point of contact,

$$x' = \left(\frac{a^4\xi}{a^2 - b^2}\right)^{\frac{1}{3}}, \tag{28}$$

$$y' = \left(-\frac{b^4\eta}{a^2 - b^2}\right)^{\frac{1}{3}}. \tag{29}$$

If these values are substituted in equation (15), we have

$$\left(\frac{a\xi}{a^2 - b^2}\right)^{\frac{2}{3}} + \left(\frac{b\eta}{a^2 - b^2}\right)^{\frac{2}{3}} = 1. \tag{30}$$

This, if ξ, η are regarded as variables, is the equation of the evolute of the ellipse, which is therefore the locus of the point P when the hyperbola and ellipse are tangent to each other.

From the property of an evolute already cited (pp. 141–2) and by reference to the figures, it is apparent that for any point on the evolute (Fig. 6) one branch of the hyperbola is tangent to the ellipse while the other branch cuts it in two points and there are three normals, PN_1, PN_2, PN_3; for

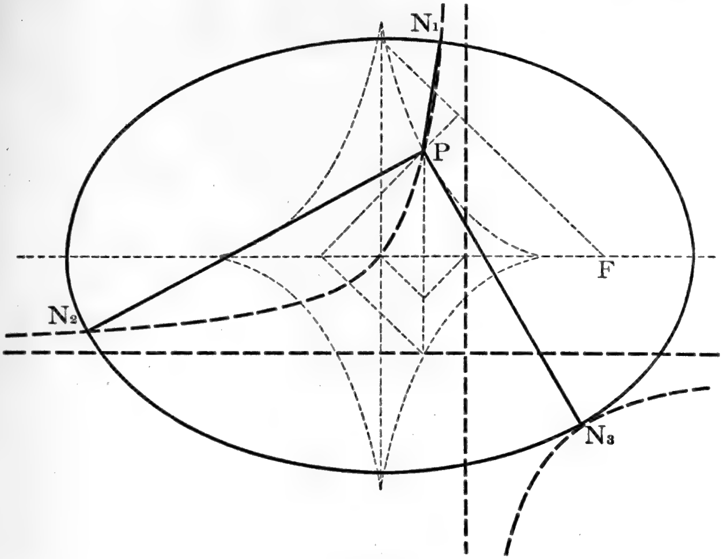

FIGURE 6.

any point in the plane on the convex side (or within) the evolute (Fig. 7), both branches of the hyperbola cut the ellipse, each in two points, and there are four normals, PN_1, PN_2, PN_3, PN_4; and for any point in the plane on the con-

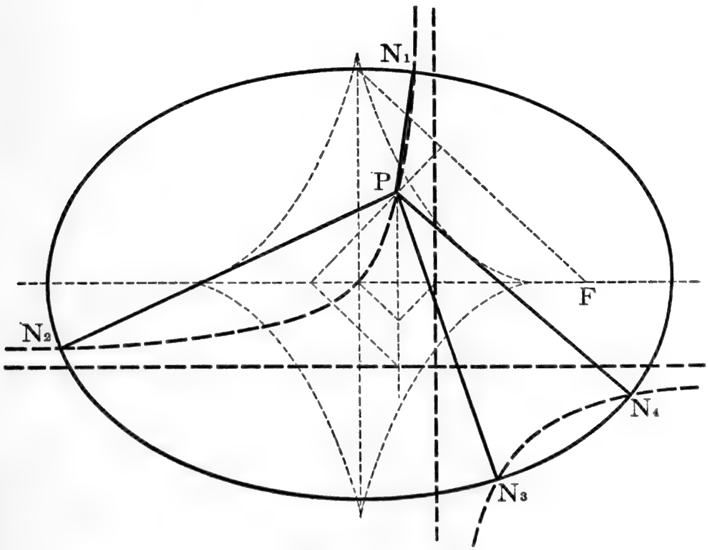

FIGURE 7.

cave side (or outside of) the evolute (Fig. 8) only one branch of the hyperbola cuts the ellipse, but this one cuts it in two points, and there are two normals, PN_1, PN_2.

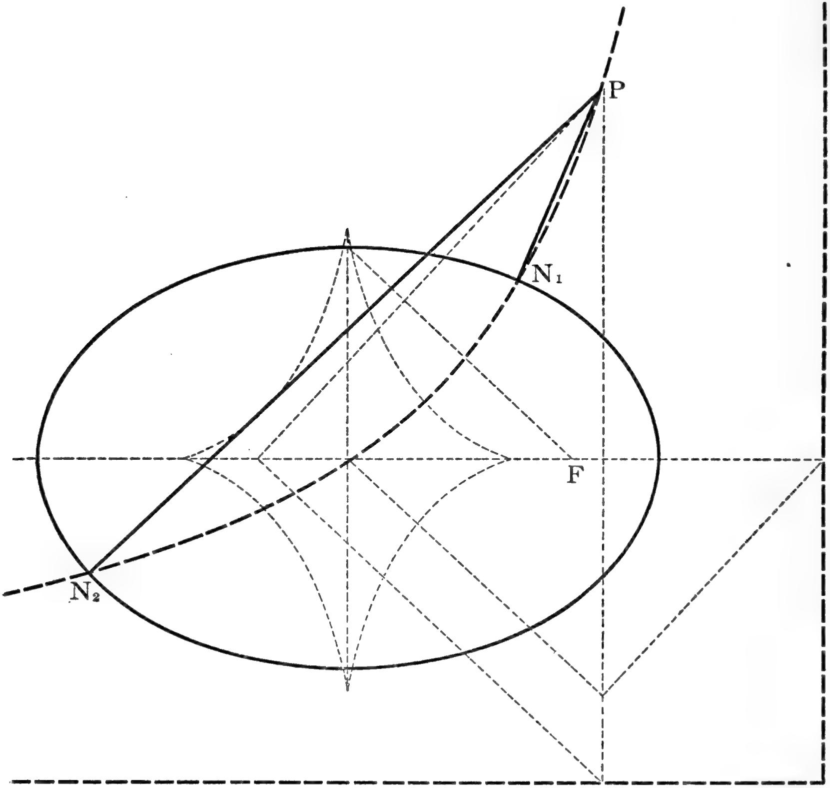

FIGURE 8.

Special Cases. 1. When the point P lies on the ellipse one of the normals through P is the tangent to the auxiliary hyperbola at that point and is readily found by joining with P a point on the asymptote parallel to the axis of X at a distance $\frac{b^2}{a^2-b^2}\xi$ from the foot of the ordinate through P. This furnishes a convenient method of drawing a normal to the ellipse at a point on the curve because no bisection of angles is required and corresponds to the method employed for the parabola by using the property that the sub-normal is constant.

2. When the given point P is on either axis of the ellipse, the auxiliary hyperbola degenerates into its asymptotes, one of which becomes the axis of the ellipse through the point, and the other is found by the construction. The intersections of these two asymptotes with the ellipse give the normals. It will be observed that when the point P is at one of the cusps of the evolute, one of the asymptotes is tangent to the ellipse, which means that three of the normals coincide.

3. For the case when the ellipse becomes a circle, $a = b$, and equation (18) becomes

$$\xi y - \eta x = 0, \qquad (31)$$

which is the equation of a straight line through P and the center of the circle; the normals, therefore, coincide with this line.

The constructions for these cases can easily be supplied by the reader.

THE NORMAL TO THE HYPERBOLA.

The equation of the hyperbola referred to its rectangular axes as axes of co-ordinates is, in the usual notation,

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1. \qquad (32)$$

The equation of the normal to the hyperbola is

$$a^2 x y_1 + b^2 y x_1 = (a^2 + b^2)\, x_1 y_1 \qquad (33)$$

in which x_1, y_1 are the co-ordinates of the point in which the normal crosses the curve.

If the normal is to be drawn through any point in the plane P whose co-ordinates are ξ, η, these co-ordinates must satisfy equation (33), so that

$$a^2 \xi y_1 + b^2 \eta x_1 = (a^2 + b^2)\, x_1 y_1. \qquad (34)$$

The co-ordinates x_1, y_1 also satisfy equation (33).

If we now make x_1, y_1 variables, equation (34) becomes

$$a^2\xi y + b^2\eta x = (a^2 + b^2)\, xy. \tag{35}$$

This equation is satisfied by the co-ordinates ξ, η and also by the co-ordinates x_1, y_1; and, therefore, represents a curve which passes through the given point P and through the intersections with the hyperbola of the normals through P.

Equation (35) represents an equilateral hyperbola, which will be designated in what follows as the auxiliary hyperbola. The equations of its asymptotes are

$$x = \frac{a^2}{a^2 + b^2}\xi \tag{36}$$

and

$$y = \frac{b^2}{a^2 + b^2}\eta. \tag{37}$$

Equation (36) represents a straight line parallel to the axis of Y and at a distance $\frac{a^2}{a^2 + b^2}\xi$ from it.

As $\frac{a^2}{a^2 + b^2}$ is necessarily positive, the expression $\frac{a^2}{a^2 + b^2}\xi$ always has the same sign as ξ; therefore, the asymptote represented by equation (36) lies on the same side of the axis of Y as the point P. And as $\frac{a^2}{a^2 + b^2}$ is less than unity, the asymptote lies between the axis of Y and the point P.

The distance from the point P to this asymptote is

$$\xi - \frac{a^2}{a^2 + b^2}\xi \equiv \frac{b^2}{a^2 + b^2}\xi. \tag{38}$$

Equation (37) represents a straight line parallel to the axis of X and at a distance $\frac{b^2}{a^2 + b^2}\eta$ from it.

As $\frac{b^2}{a^2 + b^2}$ is necessarily positive, the expression $\frac{b^2}{a^2 + b^2}\eta$ always has the same sign as η; therefore, the asymptote represented by equation (37) lies on the same side of the axis of X as the point P. And as $\frac{b^2}{a^2+b^2}$ is less than unity, the asymptote lies between the axis of X and the point P.

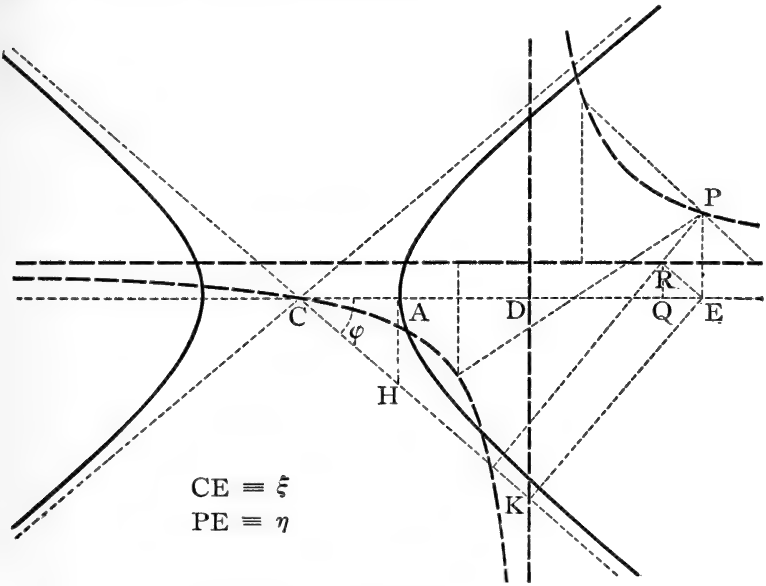

FIGURE 9.

The special construction for the asymptotes of the auxiliary hyperbola in this case is as follows:—

The asymptote parallel to the axis of Y is at a distance $\frac{b^2}{a^2+b^2}\xi$ from P. To find it, draw EK (Fig. 9) perpendicular to the asymptote of the given hyperbola. We then have, if we let $\varphi \equiv \angle ACH$,

$$\sin\varphi = \frac{b}{(a^2+b^2)^{\frac{1}{2}}},$$

$$EK = \xi \sin\varphi,$$

$$ED = EK \cdot \sin\varphi = \xi \sin^2\varphi = \frac{b^2}{a^2+b^2}\xi; \quad (39)$$

therefore, (eq. 38) the line through K parallel to the axis of Y is the required asymptote.

For the other asymptote, draw PR perpendicular to the same asymptote of the given hyperbola and ER parallel to this asymptote. We then have

$$ER = \eta \sin \varphi,$$

$$RQ = ER \cdot \sin \varphi = \eta \sin^2 \varphi = \frac{b^2}{a^2 + b^2} \eta; \quad (40)$$

therefore, (eq. 37) the line through R parallel to the axis of X is the required asymptote.

To find points on the curve, the same construction as in the previous cases may be employed, if we observe that the constant base of the triangles on the asymptote parallel to the axis of X is in this case $\frac{b^2}{a^2 + b^2} \xi$ and, therefore, equal to the distance ED.

This hyperbola will intersect the given hyperbola in two, three, or four points according to the position of the point P in the plane. The actual construction of the auxiliary hyperbola for any given case will give all the real normals possible for the given position of the point. As in the cases of the parabola and the ellipse, the number of points in which the auxiliary hyperbola cuts the given curve will determine the number of normals for any given position of the point P. Since one branch of the auxiliary hyperbola passes through the center of the given hyperbola, as is evident from equation (35), both branches of the auxiliary hyperbola cannot be tangent to the given hyperbola; and since one asymptote of the auxiliary hyperbola is parallel to the axis of X, there must be at least two real normals, one to each branch of the given hyperbola, whatever the position of the point P.

The following analysis shows in what way the number of normals possible is dependent upon the position of the point in the plane:—

The equation of the tangent to the given hyperbola may be written

$$y = \frac{b^2x'}{a^2y'}x - \frac{b^2}{y'} \tag{41}$$

in which x', y' are the co-ordinates of the point of contact on the given hyperbola.

The equation of the tangent to the auxiliary hyperbola may be written

$$y = -\frac{a^2\xi y'^2}{b^2\eta x'^2}x + \frac{(a^2 + b^2)\,y'^2}{b^2\eta} \tag{42}$$

in which x', y' are the co-ordinates of the point of contact on the auxiliary hyperbola.

If equations (41) and (42) are made to represent the same line, which signifies that the tangents to the two curves coincide, and if, at the same time, x', y' in (41) and (42) represent the same point, which means that the curves are tangent to each other at that point, we have as equations of condition,

$$\frac{b^2x'}{a^2y'} = -\frac{a^2\xi y'^2}{b^2\eta x'^2}, \tag{43}$$

$$-\frac{b^2}{y'} = \frac{(a^2 + b^2)\,y'^2}{b^2\eta}; \tag{44}$$

from which for the co-ordinates of the point of contact

$$x' = \left(\frac{a^4\xi}{a^2 + b^2}\right)^{\frac{1}{3}}, \tag{45}$$

$$y' = \left(-\frac{b^4\eta}{a^2 + b^2}\right)^{\frac{1}{3}}. \tag{46}$$

If these values are substituted in equation (32), we have

$$\left(\frac{a\xi}{a^2 + b^2}\right)^{\frac{2}{3}} - \left(\frac{b\eta}{a^2 + b^2}\right)^{\frac{2}{3}} = 1. \tag{47}$$

This, if ξ, η are regarded as variables, is the equation of the evolute of the hyperbola, which is, therefore, the locus of the point P when the auxiliary and given hyperbolae are tangent to each other. From the property of the evolute already cited (pp. 141–2) and by reference to the figures, it is apparent that for any point on the evolute (Fig. 10) one branch of the auxiliary hyperbola is tangent to one branch of the given hyperbola and cuts the other branch of the given hyperbola in

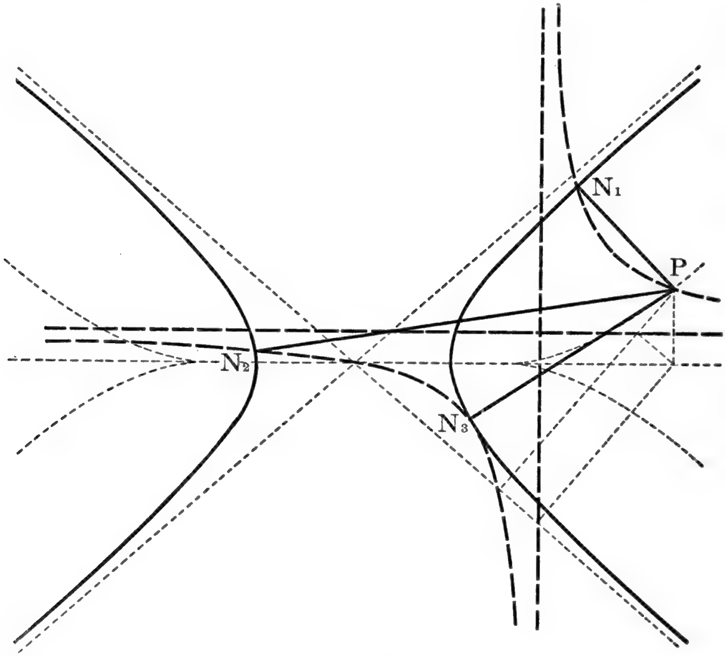

FIGURE 10.

a single point, while the other branch of the auxiliary hyperbola cuts one branch of the given hyperbola in a single point and there are three normals, PN_1, PN_2, PN_3; for any point in the plane on the convex side of either branch of the evolute (Fig. 11), one branch of the auxiliary hyperbola cuts one branch of the given hyperbola in two points and cuts the other branch of the given hyperbola in a single point, while the other branch of the auxiliary hyperbola cuts the one branch of the given hyperbola in a single point and there are four normals, PN_1, PN_2, PN_3, PN_4; and for any point in the plane on the concave side of both branches of the evolute (Fig. 12), one branch of the auxiliary hyperbola cuts one

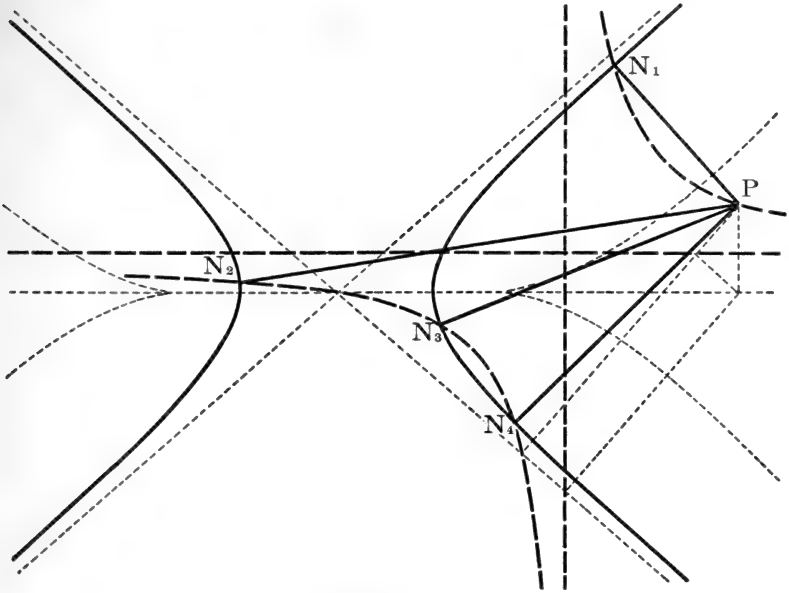

FIGURE 11.

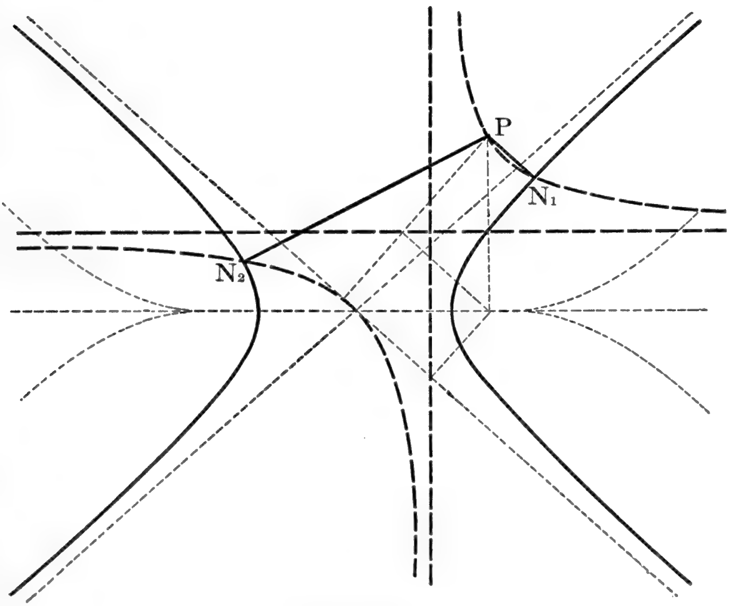

FIGURE 12.

branch, and the other branch of the auxiliary hyperbola cuts the other branch of the given hyperbola each in a single point and there are two normals, PN_1, PN_2.

Special Cases. 1. When the point P lies on the given hyperbola one of the normals through the point is tangent to the auxiliary hyperbola at that point and is found precisely as in the case of the ellipse, if we observe that the constant base of the triangles on the asymptote parallel to the axis of X is $\frac{b^2}{a^2+b^2}\xi$.

2. If the given point P is on either of the axes of the given hyperbola, the auxiliary hyperbola degenerates into its asymptotes, one of which is the axis of the given hyperbola through the point, the other is obtained by the construction. The intersections of these asymptotes with the given hyperbola give the normals. It will be observed that if the given point P is at one of the cusps of the evolute the asymptote parallel to the axis of Y is tangent to the hyperbola and, therefore, three of the normals coincide.

The constructions for these cases can easily be supplied by the reader.

THE NORMAL TO THE CONJUGATE HYPERBOLA.

The equation of the hyperbola conjugate to the one represented by equation (32) is

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = -1. \tag{48}$$

The auxiliary hyperbola which gives the normals through P for this hyperbola is

$$a^2\xi y + b^2\eta x = (a^2 + b^2)\,xy, \tag{49}$$

which is identical with equation (35). From this it appears that the same auxiliary hyperbola gives the normals not only for the original hyperbola but for the conjugate hyperbola as well, as is shown in Fig. 13, in which the point P is so situated

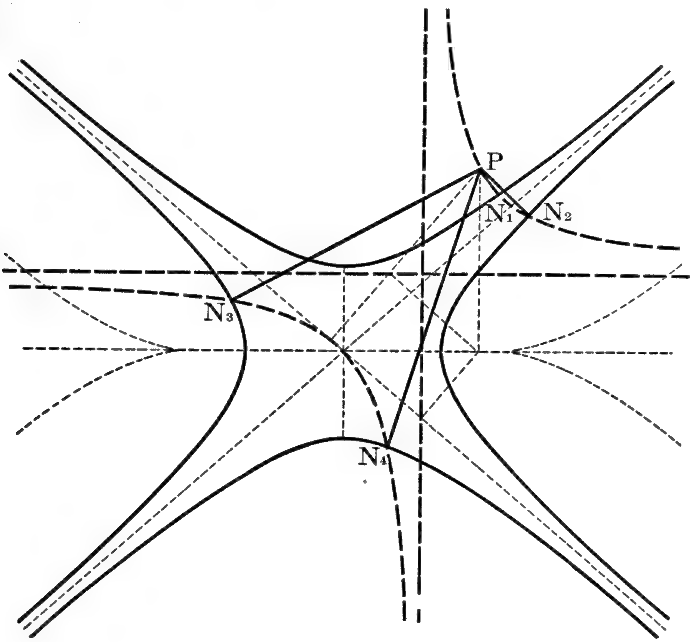

FIGURE 13.

that there are two normals, PN_2, PN_3, to the original hyperbola and two normals, PN_1, PN_4, to the conjugate hyperbola.

Issued July 15, 1898.

160

CONTRIBUTION TO THE FOSSIL FLORA OF FLORISSANT, COLORADO.*

WALTER C. G. KIRCHNER.

The region about Florissant, Colorado, has become famous for its prolific beds of plants and insects, and is regarded with much interest by the paleontologist. The remarks which follow are based on the results of a trip to this region and also on the examination of an interesting collection of fossil plants which were obtained from the same locality. The collection, which includes many hundred specimens, was made by Dr. G. Hambach and is now in the possession of Washington University.

A careful investigation of the material has led to the compilation of a catalogue of the fossil plants found at Florissant, and has shown that the collection contains several species which have not hitherto been described. The collection also contains a few plants which, if not entirely new, have not been mentioned as being found at Florissant.

The first published account of the region about Florissant is found in the report of Mr. A. C. Peale on the geology of Hayden Park. The account is short and makes mention of only a few fossil plants. A better account is found in a report by Professor Samuel H. Scudder, entitled "The Tertiary Lake basin at Florissant, Colorado, between South and Hayden Parks." This report gives a detailed account of the geology of the place and an interesting synopsis of its paleontology. Mr. Leo Lesquereux, who for a number of years was the government paleontologist, has done most toward contributing to a knowledge of the fossil flora of the Western States and Territories. His works have proved an invaluable aid.

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* Presented in abstract before The Academy of Science of St. Louis, June 6, 1898.

The plants found at Florissant belong to the Tertiary period and to that division known as the Green River group. The shales in which the fossil plants occur are composed of volcanic sand and ash, and are mostly drab, light-gray or light-brown in color. Some of the plants have been beautifully preserved.

In the enumeration of species of the Green River group, Mr. Lesquereux states that out of 228 species 152 were found at Florissant. From the present catalogue it will be seen that the list has been increased and that 213 species can now with apparent safety be included in the flora of Florissant.

I am greatly indebted to our paleontologist, Dr. G. Hambach, for the privilege of examining his private collection and for the kind assistance he has rendered in the preparation of this work. To a number of others who have enabled me to carry on the work, I should also like to extend my sincere thanks.

In the nomenclature of some of the species, I have been permitted to use the names of Dr. Gustav Hambach, Professor Edmund A. Engler, President of the Academy of Science, and Mr. D. S. Brown, who by his munificence has materially aided the department of Natural Science in Washington University.

CATALOGUE OF PLANTS.

CRYPTOGAMAE.

Characeae.

1. Chara? glomerata, Lesqx. Rept. U. S. Geol. Surv. **8**: 135.

Musci.

2. Fontinalis pristina, Lesqx. Rept. U. S. Geol. Surv. **8**: 135.

3. Hypnum Brownii, sp. nov. Infra, p. 178. Pl. XII. fig. 4, 4a. *Dr. Hambach.*

4. H. Haydenii, Lesqx. Rept. U. S. Geol. Surv. **7**: 44.

Rhizocarpeae.

Salvinia Alleni, Lesqx.=Tmesipteris Alleni (5).

S. cyclophylla, Lesqx.=Phyllites cyclophyllus (48).

Lycopodiaceae.

5. Tmesipteris Alleni, (Lesqx.) Hollick, Bull. Torr. Bot. Club. **21**: 256.
Salvinia Alleni, Lesqx. Rept. U. S. Geol. Surv. **7**: 65.
Ophioglossum Alleni, Lesqx. Ann. Rept. U. S. Geol. Surv. **1872**: 371.

Isoeteae.

6. Isoetes brevifolius, Lesqx. Rept. U. S. Geol. Surv. **8**: 136.

Filices.

7. Adiantites gracillimus, Lesqx. Rept. U. S. Geol. Surv. **8**: 137.

8. Asplenium (Diplazium) Crossii, nom. nov. Knowlton, Cat. Cret. and Tert. Pl. N. Am. **1898**: 44.
Diplazium Muelleri, Heer. Rept. U. S. Geol. Surv. **7**: 55.

Diplazium Muelleri, Heer.=Asplenium Crossii (8).

9. Sphenopteris Guyottii, Lesqx. Rept. U. S. Geol. Surv. **8**: 137. *Wash. Univ.*

Coniferae.

10. Glyptostrobus Europaeus, Heer, Ann. Rept. U. S. Geol. Surv. **1873**: 409. — Rept. U. S. Geol. Surv. **7**: 74.

11. G. Ungeri? Heer, Rept. U. S. Geol. Surv. **8**: 139. — Knowlton, Cat. Cret. and Tert. Pl. N. Am. **1898**: 113. *Wash. Univ.*
It is probably the same as *G. Europaeus Ungeri*, Heer, Rept. U. S. Geol. Surv. **8**: 222.

12. Pimelia delicatula, Lesqx. Rept. U. S. Geol. Surv. **8**: 168.

13. PINUS FLORISSANTI, Lesqx. Rept. U. S. Geol. Surv. **8**: 138.

14. P. HAMBACHI, sp. nov. Infra, p. 179. Pl. XIII. fig. 3. *Wash. Univ.*

15. P. PALAEOSTROBUS? (Ett.) Heer, Rept. U. S. Geol. Surv. **7**: 83.
P. polaris, Heer, Ann. Rept. U. S. Geol. Surv. **1873**: 410.

P. polaris, Heer.=Pinus palaeostrobus (15).

16. PODOCARPUS EOCENICA? Ung. Rept. U. S. Geol. Surv. **8**: 140.

17. SEQUOIA AFFINIS, Lesqx. Rept. U. S. Geol. Surv. **7**: 75.

18. S. LANGSDORFII, (Brgt.) Heer, Rept. U. S. Geol. Surv. **7**: 76.

19. TAXODIUM DISTICHUM MIOCENICUM, Heer. Scudder, Bull. U. S. Geol. Surv. **6**, no. 2: 297.

20. THUITES CALLITRINA, Ung. Ann. Rept. U. S. Geol. Surv. **1872**: 371.

21. WIDDRINGTONIA LINGUAEFOLIA, Lesqx. Rept. U. S. Geol. Surv. **8**: 139.

MONOCOTYLEDONES.

TYPHACEAE.

22. NAJADOPSIS RUGULOSA, Lesqx. Rept. U. S. Geol. Surv. **8**: 142.

23. POTAMOGETON GENICULATUS, Al. Br. Rept. U. S. Geol. Surv. **8**: 142.

24. POTAMOGETON VERTICILLATUS, Lesqx. Rept. U. S. Geol. Surv. **8**: 142.

25. TYPHA LATISSIMA, Al. Br. Rept. U. S. Geol. Surv. **8**: 141.

AROIDEAE.

26. ACORUS AFFINIS, Lesqx. Ann. Rept. U. S. Geol. Surv. **1873**: 410. Not afterwards recognized.

27. ACORUS BRACHYSTACHYS, Heer. (?) Rept. U. S. Geol. Surv. **7**: 105.

LEMNACEAE.

28. LEMNA PENICILLATA, Lesqx. Rept. U. S. Geol. Surv. **8**: 143.

PALMAE.

29. PALMOCARPON? GLOBOSUM, Lesqx. Rept. U. S. Geol. Surv. **8**: 144.

DICOTYLEDONES.

MYRICACEAE.

Callicoma microphylla? Ett.=Myrica Drymeja (34).

30. MYRICA ACUMINATA, Ung. Rept. U. S. Geol. Surv. **7**: 130. —Ann. Rept. U. S. Geol. Surv. **1873**: 411.

31. M. AMYGDALENA, Sap. Rept. U. S. Geol. Surv. **8**: 147.

32. M. BOLANDERI, Lesqx. Rept. U. S. Geol. Surv. **7**: 133. Florissant?

M. callicomaefolia, Lesqx. = Myrica Drymeja (34).

33. M. COPEANA, Lesqx. Rept. U. S. Geol. Surv. **7**: 131. —Ann. Rept. U. S. Geol. Surv. **1873**: 411.

M. diversifolia, Lesqx. = Crataegus flavescens (181).

34. MYRICA DRYMEJA, (Lesqx). n. comb. Knowlton, Cat. Cret. and Tert. Pl. N. Am. **1898**: 146. *Wash. Univ.*
Myrica callicomaefolia, Lesqx. Rept. U. S. Geol. Surv. **8**: 146.
Callicoma microphylla, Ett. Rept. U. S. Geol. Surv. **7**: 246.

35. M. FALLAX, Lesqx. Rept. U. S. Geol. Surv. **8**: 147. *Wash. Univ.*

36. M. INSIGNIS, Lesqx. Rept. U. S. Geol. Surv. **7**: 135.—Ann. Rept. U. S. Geol. Surv. **1874**: 312.

37. M. LATILOBA, Heer, var. ACUTILOBA, Lesqx. Rept. U. S. Geol. Surv. **7**: 134.

38. Myrica obscura, Lesqx. Rept. U. S. Geol. Surv. **8**: 145. *Wash. Univ.*

39. M. polymorpha, Lesqx. Rept. U. S. Geol. Surv. **8**: 146. *Wash. Univ.*

40. M. rigida, Lesqx. Rept. U. S. Geol. Surv. **8**: 145. *Wash. Univ.*

41. M. Scottii, Lesqx. Rept. U. S. Geol. Surv. **8**: 147. *Wash. Univ.*

42. M. Zachariensis, Sap. Rept. U. S. Geol. Surv. **8**: 146.

Betulaceae.

43. Alnus cordata, Lesqx. Rept. U. S. Geol. Surv. **8**: 151.

44. A. Kefersteinii, Goepp. Rept. U. S. Geol. Surv. **7**: 140.

45. Betula dryadum, Brongn. Scudder, Bull. U. S. Geol. Surv. **6**, no. 2: 297.

46. B. Florissanti, Lesqx. Rept. U. S. Geol. Surv. **8**: 150.

47. B. truncata, Lesqx. Rept. U. S. Geol. Surv. **8**: 150.

48. Phyllites cyclophyllus, (Lesqx). Hollick, Bull. Torr. Bot. Club. **21**: 256 (1894).
    Salvinia cyclophylla, Lesqx. Ann. Rept. U. S. Geol. Surv. **1878**: 408. — Rept. U. S. Geol. Surv. **7**: 64, 315.

Cupuliferae.

49. Carpinus attenuata, Lesqx. Rept. U. S. Geol. Surv. **8**: 152. *Wash. Univ.*

50. C. fraterna, Lesqx. Rept. U. S. Geol. Surv. **8**: 152. *Wash. Univ.*

51. C. grandis, Ung. Rept. U. S. Geol. Surv. **7**: 143.

52. C. pyramidalis, Heer. Scudder, Bull. U. S. Geol. Surv. **6**, no. 2: 297.

53. CASTANEA INTERMEDIA, Lesqx. Rept. U. S. Geol. Surv. **7**: 164.

54. OSTRYA BETULOIDES, Lesqx. Rept. U. S. Geol. Surv. **8**: 151.

55. QUERCUS ANTECEDENS, Sap. Scudder, Bull. U. S. Geol. Surv. **6**, no. 2: 297.

56. Q. DRYMEJA, Ung. Ann. Rept. U. S. Geol. Surv. **1871**: 308.— Scudder, Bull. U. S. Geol. Surv. **6**, no. 2: 297. — Rept. U. S. Geol. Surv. **8**: 154.

57. Q. ELAENA, Ung. Rept. U. S. Geol. Surv. **8**: 155.

58. Q. ELAENOIDES, Lesqx. Mem. Mus. Comp. Zool. **6**, no. 2: 4.

59. Q. MEDITERRANEA, Ung. Rept. U. S. Geol. Surv. **8**: 153.

60. Q. NERIIFOLIA, Al. Br. Rept. U. S. Geol. Surv. **7**: 150. — Ann. Rept. U. S. Geol. Surv. **1873**: 411. Identification said to be doubtful.

61. Q. OSBORNII, Lesqx. Rept. U. S. Geol. Surv. **8**: 154.

62. Q. PYRIFOLIA, Lesqx. Rept. U. S. Geol. Surv. **8**: 154.

63. Q. SALICINA, Sap. Scudder, Bull. U. S. Geol. Surv. **6**, no. 2: 297.

64. Q. SERRA, Ung. Rept. U. S. Geol. Surv. **8**: 153.

SALICINEAE.

65. POPULUS ARCTICA, Heer, Rept. U. S. Geol. Surv. **8**: 159. *Wash. Univ.*

66. P. BALSAMOIDES? Goepp. var. LATIFOLIA, Lesqx. Rept. U. S. Geol. Surv. **8**: 158.

67. P. HEERII, Sap. Rept. U. S. Geol. Surv. **8**: 157. *Wash. Univ.*

68. P. OXYPHYLLA, Sap. Rept. U. S. Geol. Surv. **8**: 159.

69. P. Zaddachi, Heer, Rept. U. S. Geol. Surv. **8**: 158.

70. P. pyrifolia sp. nov. Infra, p. 185. Plate XV. fig. 4. *Wash. Univ.*

71. Salix amygdalaefolia, Lesqx. Rept. U. S. Geol. Surv. **8**: 156. *Wash. Univ.*

72. S. integra, Goepp. Scudder, Bull. U. S. Geol. Surv. **6**, no. 2: 297. — Rept. U. S. Geol. Surv. **7**: 167.

73. S. Lavateri, Heer. Scudder, Bull. U. S. Geol. Surv. **6**, no. 2: 297.

74. S. Libbeyi, Lesqx. Rept. U. S. Geol. Surv. **8**: 156.

75. S. media, Heer. Scudder, Bull. U. S. Geol. Surv. **6**, no. 2: 297. — Rept. U. S. Geol. Surv. **7**: 168.

76. S. varians, Goepp. Scudder, Bull. U. S. Geol. Surv. **6**, no. 2: 297.

Ulmaceae.

77. Celtis McCoshii, Lesqx. Rept. U. S. Geol. Surv. **8**: 163.

78. Planera longifolia, Lesqx. Rept. U. S. Geol. Surv. **7**: 189. *Wash. Univ.*

79. P. longifolia, var. myricaefolia, Lesqx. Rept. U. S. Geol. Surv. **8**: 161. *Wash. Univ.*

80. P. Ungeri, Ett. Rept. U. S. Geol. Surv. **7**: 190.

81. Ulmus Braunii, Heer, Rept. U. S. Geol. Surv. **8**: 161. *Wash. Univ.*

82. U. Brownellii, Lesqx. Rept. U. S. Geol. Surv. **8**: 160. *Wash. Univ.*

83. U. Fischeri, Heer. Scudder, Bull. U. S. Geol. Surv. **6**, no. 2: 296.

84. U. Hilliae, Lesqx. Rept. U. S. Geol. Surv. **8**: 160. *Wash. Univ.*

85. U. tenuinervis, Lesqx. Rept. U. S. Geol. Surv. **7**: 188.

MOREAE.

86. FICUS HAYDENII, Lesqx. Rept. U.S. Geol. Surv. **7**: 197. *Wash. Univ.*

87. F. LANCEOLATA, Heer, Rept. U. S. Geol. Surv. **7**: 192. — Ann. Rept. U. S. Geol. Surv. **1873**: 414.

SANTALEAE.

88. SANTALUM AMERICANUM, Lesqx. Rept. U. S. Geol. Surv. **8**: 164.

PROTEACEAE.

89. BANKSITES LINEATUS, Lesqx. Rept. U. S. Geol. Surv. **8**: 165.

90. LOMATIA ABBREVIATA, Lesqx. Rept. U. S. Geol. Surv. **8**: 167.

91. L. ACUTILOBA, Lesqx. Rept. U. S. Geol. Surv. **8**: 167. *Wash. Univ.*

92. L. HAKEAEFOLIA, Lesqx. Rept. U. S. Geol. Surv. **8**: 166.

93. L. INTERRUPTA, Lesqx. Rept. U. S. Geol. Surv. **8**: 167. *Wash. Univ.*

94. L. SPINOSA, Lesqx. Rept. U. S. Geol. Surv. **8**: 166.

95. L. TERMINALIS, Lesqx. Rept. U. S. Geol. Surv. **8**: 166. *Wash. Univ.*

96. L. TRIPARTITA, Lesqx. Rept. U. S. Geol. Surv. **8**: 167.

PIMELEAE.

97. PIMELEA DELICATULA, Lesqx. Rept. U. S. Geol. Surv. **8**: 168.

OLEACEAE.

98. FRAXINUS ABBREVIATA, Lesqx. Rept. U. S. Geol. Surv. **8**: 170.

99. F. BROWNELLII, Lesqx. Scudder, Bull. U. S. Geol. Surv. **6**, no. 2 : 296.

100. F. HEERII, Lesqx. Rept. U. S. Geol. Surv. **8** : 169.

101. F. LIBBEYI, Lesqx. Rept. U. S. Geol. Surv. **8**: 171.

102. F. MESPILIFOLIA, Lesqx. Rept. U. S. Geol. Surv. **8** : 169.

103. FRAXINUS? MYRICAEFOLIA, Lesqx. Rept. U. S. Geol. Surv. **8** : 170.

104. F. PRAEDICTA, Heer, Rept. U. S. Geol. Surv. **8**: 169.

105. F. UNGERI, Lesqx. Rept. U. S. Geol. Surv. **8**: 171.

106. OLEA PRAEMISSA, Lesqx. Rept. U. S. Geol. Surv. **8**: 168.

APOCYNEAE.

107. APOCYNOPHYLLUM SCUDDERI, Lesqx. Rept. U. S. Geol. Surv. **8**: 172. *Dr. Hambach.*

CONVOLVULACEAE.

108. PORANA SPEIRII, Lesqx. Rept. U. S. Geol. Surv. **8**: 172.

109. P. TENUIS, Lesqx. Rept. U. S. Geol. Surv. **8** : 173.

MYRSINEAE.

110. MYRSINE LATIFOLIA, Lesqx. Rept. U. S. Geol. Surv. **8** : 173.

SAPOTACEAE.

111. BUMELIA FLORISSANTI, Lesqx. Rept. U. S. Geol. Surv. **8** : 174.

EBENACEAE.

112. DIOSPYROS BRACHYSEPALA, Al. Br. Rept. U. S. Geol. Surv. **8**: 174.

113. D. COPEANA, Lesqx. Rept. U. S. Geol. Surv. **7**: **232**.

114. D. CUSPIDATA, sp. nov. Infra, p. 185. Plate XII. fig. 1. *Dr. Hambach.*

115. MACREIGHTIA CRASSA, Lesqx. Rept. U. S. Geol. Surv. **8**: 175.

ERICACEAE.

116. ANDROMEDA RHOMBOIDALIS, Lesq. Rept. U. S. Geol. Surv. **8**: 176.

117. VACCINIUM RETICULATUM? Al. Br. Rept. U. S. Geol. Surv. **7**: 235.

ARALIACEAE.

118. ARALIA DISSECTA, Lesqx. Rept. U. S. Geol. Surv. **8**: 176.

119. HEDERA MARGINATA, Lesqx. Rept. U. S. Geol. Surv. **8**: 177.

HAMAMELIDAE.

120. LIQUIDAMBAR EUROPAEUM, Al. Br. Scudder, Bull. U. S. Geol. Surv. **6**, no. 2: 296. — Rept. U. S. Geol. Surv. **8**: 159.

MAGNOLIACEAE.

121. CARPITES PEALEI, Lesqx. Rept. U. S. Geol. Surv. **7**: 306.

122. C. MILIOIDES, Lesqx. Rept. U. S. Geol. Surv. **8**: 204.

SAXIFRAGEAE.

123. WEINMANNIA HAYDENII, Lesqx. Rept. U. S. Geol. Surv. **8**: 178. *Wash. Univ.*

Rhus Haydenii, Lesqx. Ann. Rept. U. S. Geol. Surv. **1873**: 417. — Rept. U. S. Geol. Surv. **7**: 294, 327.

124. WEINMANNIA INTEGRIFOLIA, Lesqx. Rept. U. S. Geol. Surv. **8**: 178.

125. W. OBTUSIFOLIA, Lesqx. Rept. U. S. Geol. Surv. **8**: 178.

Malvaceae.

126. Sterculia Engleri, sp. nov. Infra, p. 180. Pl. XIV. fig. 3. *Wash. Univ.*

127. S. rigida, Lesqx. Rept. U. S. Geol. Surv. **8**: 179.

Tiliaceae.

128. Tilia populifolia, Lesqx. Rept. U. S. Geol. Surv. **8**: 179. *Wash. Univ.*

Aceraceae.

129. Acer Florissanti, sp. nov. Infra, p. 181. Pl. XI. fig. 1. *Wash. Univ.*

130. A. mysticum, sp. nov. Infra, p. 181. Pl. XI. fig. 2. *Wash. Univ.*

131. A., species, Lesqx. Rept. U. S. Geol. Surv. **8**: 181.

Sapindaceae.

132. Dodonaea, species, Lesqx. Rept. U. S. Geol. Surv. **8**: 182. *Wash. Univ.*

133. Sapindus angustifolius, Lesqx. Rept. U. S. Geol. Surv. **7**: 265. *Wash. Univ.*

134. S. inflexus, Lesqx. Rept. U. S. Geol. Surv. **8**: 182.

135. S. lanceofolius, Lesqx. Rept. U. S. Geol. Surv. **8**: 182.

136. S. obtusifolius, Lesqx. Rept. U. S. Geol. Surv. **7**: 266. **8**: 181, 210.

137. S. stellariaefolius, Lesqx. Rept. U. S. Geol. Surv. **7**: 264.

Staphyleaceae.

138. Staphylea acuminata, Lesqx. Rept. U. S. Geol. Surv. **7**: 267, 326. *Dr. Hambach.*

Frangulaceae.

139. Celastrinites elegans, Lesqx. Rept. U. S. Geol. Surv. **8** : 185.

140. Celastrus fraxinifolius, Lesqx. Rept. U. S. Geol. Surv. **8** : 184.

141. C. Greithianus, Heer, Rept. U. S. Geol. Surv. **8** : 184.

142. C. Lacoei, Lesqx. Rept. U. S. Geol. Surv. **8**: 184.

Iliceae.

143. Ilex grandifolia, Lesqx. Rept. U. S. Geol. Surv. **8** : 187.

144. I. knightiaefolia, Lesqx. Rept. U. S. Geol. Surv. **8**: 188.

145. I. microphylla, Lesqx. Rept. U. S. Geol. Surv. **8**: 186.

146. I. pseudo-stenophylla, Lesqx. Rept. U. S. Geol. Surv. **8**: 185.

147. I. quercifolia, Lesqx. Rept. U. S. Geol. Surv. **8**: 186.

148. I. rigida, sp. nov. Infra, p. 182. Pl. XIV. fig. 2. *Wash. Univ.*

149. I. sphenophylla? Heer. Lesqx. Ann. Rept. U. S. Geog. Surv. **1873** : 415.

150. I. subdenticulata, Lesqx. Rept. U. S. Geol. Surv. **7** : 271. — Ann. Rept. U. S. Geol. Surv. **1873** : 416.

Rhamneae.

151. Paliurus Florissanti, Lesqx. Rept. U. S. Geol. Surv. **7**: 274. — Ann. Rept. U. S. Geol. Surv. **1873** : 416.

152. P. orbiculatus, Sap. Rept. U. S. Geol. Surv. **8** : 188.

153. Rhamnus ellipticus, sp. nov. Infra, p. 183. Pl. XV. fig. 3. *Wash. Univ.*

154. R. NOTATUS? Sap. Rept. U. S. Geol. Surv. **8**: 189.

155. R. OLEAEFOLIUS, Lesqx. Rept. U. S. Geol. Surv. **8**: 188.

156. ZIZYPHUS OBTUSA, sp. nov. Infra, p. 182. Pl. XIII. fig. 1. *Wash. Univ.*

JUGLANDEAE.

Carya bilinica, (Ung.) = Hicoria juglandiformis (158).

C. Bruckmanni? Heer. = Hicoria Bruckmanni (157, a).

C. rostrata, (Goepp.) Schp. = Hicoria rostrata (159).

157. ENGELHARDTIA OXYPTERA, Sap. Rept. U. S. Geol. Surv. **8**: 192.

157, a. HICORIA BRUCKMANNI, (Heer.) n. comb. Knowlton, Cat. Cret. and Tert. Pl. N. Am. **1898**: 117.
Carya Bruckmanni? Heer. Lesqx. Rept. U. S. Geol. Surv. **8**: 191.

158. H. JUGLANDIFORMIS, (Sternb.) n. comb. Knowlton, Cat. Cret. and Tert. Pl. N. Am. **1898**: 117.
Carya bilinica, (Ung.) Ett. Lesqx. Rept. U. S. Geol. Surv. **8**: 191.

159. H. ROSTRATA, (Goepp.) n. comb. Knowlton, Cat. Cret. and Tert. Pl. Am. **1898**: 118.
Carya rostrata, (Goepp.) Schimp. Lesqx. Rept. U. S. Geol. Surv. **8**: 191.

160. JUGLANS AFFINIS, sp. nov. Infra, p. 184. Pl. XIII. fig. 2. *Wash. Univ.*

161. J. COSTATA, Ung. Rept. U. S. Geol. Surv. **8**: 190.

162. J. CROSSII, nom. nov. Knowlton, Cat. Cret. and Tert. Pl. N. Am. **1898**: 122. — Infra, p. 183. Pl. XIV. fig. 1. *Wash. Univ.*
Juglans denticulata, Heer. Lesqx. Rept. U. S. Geol. Surv. **7**: 289. — Ann. Rept. U. S. Geol. Surv. **1871**: 298.
J. denticulata, Heer, 1869, preoccupied by *J. denticulata,* O. Web. 1852.

J. denticulata, Heer. = Juglans Crossii (162).

163. J. FLORISSANTI, Lesqx. Rept. U. S. Geol. Surv. **8**: 190.

164. J. THERMALIS, Lesqx. Rept. U. S. Geol. Surv. **7**: 287, 327.— Scudder, Bull. U. S. Geol. Surv. **6**, no. 2: 297.

165. PTEROCARYA AMERICANA, Lesqx. Rept. U. S. Geol. Surv. **7**: 290, 327.

ANACARDIACEAE.

166. RHUS ACUMINATA, Lesqx. Rept. U. S. Geol. Surv. **8**: 194. *Wash. Univ.*

167. R. CASSIOIDES, Lesqx. Rept. U. S. Geol. Surv. **8**: 193.

168. R. CORIARIOIDES, Lesqx. Rept. U. S. Geol. Surv. **8**: 193.

169. R. EVANSII, Lesqx. Ann. Rept. U. S. Geol. Surv. **1871**: 293. **1872**: 402. — Rept. U. S. Geol. Surv. **7**: 291, 327.

170. R. FRATERNA, Lesqx. Rept. U. S. Geol. Surv. **8**: 192. *Wash. Univ.*

171. R. HILLIAE, Lesqx. Rept. U. S. Geol. Surv. **8**: 194. *Wash. Univ.*

R. Haydenii, Lesqx. = Weinmannia Haydenii (123).

172. R. ROSAEFOLIA, Lesqx. Rept. U. S. Geol. Surv. **7**: 293.

173. R. ROTUNDIFOLIA, sp. nov. Infra, p. 184. Pl. XII. fig. 2. *Dr. Hambach.*

174. R. SUBRHOMBOIDALIS, Lesqx. Rept. U. S. Geol. Surv. **8**: 195.

175. R. TRIFOLIOIDES, Lesqx. Rept. U. S. Geol. Surv. **8**: 196.

176. R. VEXANS, Lesqx. Rept. U. S. Geol. Surv. **8**: 195.

ZANTHOXYLEAE.

177. ZANTHOXYLON SPIREAEFOLIUM, Lesqx. Rept. U. S. Geol. Surv. **8**: 196.

ROSIFLORAE.

178. AMELANCHIER TYPICA, Lesqx. Rept. U. S. Geol. Surv. **8**: 198.

179. AMYGDALUS GRACILIS, Lesqx. Rept. U. S. Geol. Surv. **8**: 199.

180. CRATAEGUS ACERIFOLIA, Lesqx. Rept. U. S. Geol. Surv. **8**: 198.

181. C. FLAVESCENS, Newby. Proc. U. S. Nat. Mus. **5**: 507.
Myrica diversifolia, Lesqx. Rept. U. S. Geol. Surv. **8**: 148.

182. ROSA HILLIAE, Lesqx. Rept. U. S. Geol. Surv. **8**: 199.

LEGUMINOSAE.

183. ACACIA SEPTENTRIONALIS, Lesqx. Rept. U. S. Geol. Surv. **7**: 299.

Caesalpina? linearis, Lesqx. = Mimosites linearis (191).

184. CASSIA FISCHERI, Heer, Rept. U. S. Geol. Surv. **8**: 202.

185. CERCIS PARVIFOLIA, Lesqx. Rept. U. S. Geol. Surv. **8**: 201.

186. CYTISUS FLORISSANTIANUS, Lesqx. Rept. U. S. Geol. Surv. **8**: 200.

187. C. MODESTUS, Lesqx. Rept. U. S. Geol. Surv. **8**: 200.

188. DALBERGIA CUNEIFOLIA, Heer, Rept. U. S. Geol. Surv. **8**: 200.

189. LEGUMINOSITES, species, Lesqx. Rept. U. S. Geol. Surv. **8**: 203.

190. L. SERRULATUS, Lesqx. Rept. U. S. Geol. Surv. **8**: 202.

Mimosites linearifolius, Lesxq. = Mimosites linearis (191).

191. Mimosites linearis, (Lesqx.) n. comb. Knowlton, Cat. Cret. and Tert. Pl. N. Am. **1898**: 144. *Wash. Univ.*
Mimosites linearifolius, Lesqx. Rept. U. S. Geol. Surv. **7**: 300.
Caesalpinia? linearis, Lesqx. Ann. Rept. U. S. Geol. Surv. **1873**: 417.

192. Podogonium acuminatum, Lesqx. Rept. U. S. Geol. Surv. **8**: 201.

193. P. americanum, Lesqx. Rept. U. S. Geol. Surv. **7**: 298. **8**: 212.
Podogonium, sp., Lesqx. Ann. Rept. U. S. Geol. Surv. **1873**: 417.

Incertae Sedis.

194. Ailanthus, species, Scudder, Bull. U. S. Geol. Surv. **6**, no. 2: 296.

195. Antholithes amoenus, Lesqx. Rept. U. S. Geol. Surv. **8**: 203.

196. A. improbus, Lesqx. Rept. U. S. Geol. Surv. **8**: 204. Florissant?

197. A. obtusilobus, Lesqx. Rept. U. S. Geol. Surv. **8**: 203.

198. Asplenium tenerum, Lesqx. Rept. U. S. Geol. Surv. **8**: 221. *Dr. Hambach.*

199. Bombax, species, Scudder, Bull. U. S. Geol. Surv. **6**, no. 2: 296.

200. Carpites gemmaceus, Lesqx. Rept. U. S. Geol. Surv. **8**: 204.

201. Carpolithes, species, Lesqx. Ann. Rept. U. S. Geol. Surv. **1873**: 418.

202. Catalpa, species, Scudder, Bull. U. S. Geol. Surv. **6**, no. 2: 296.

203. Colutea, species, Scudder, Bull. U. S. Geol. Surv. **6**, no. 2: 296.

204. Convulvulaceae? sp. nov. Infra, p. 187. Pl. XV. fig. 2.

205. Corylus McQuarryi, Heer, Ann. Rept. U. S. Geol. Surv. **1871**: 308.

206. Fagus Antipofii, Heer, Ann. Rept. U. S. Geol. Surv. **1871**: 308.

207. Iris, species, Scudder, Bull. U. S. Geol. Surv. **6**, no. 2: 297.

208. Onagraceae? sp. nov. Infra, p. 186. Pl. XV. fig. 1.

209. Palaeocarya, species, Scudder, Bull. U. S. Geol. Surv. **6**, no. 2: 297.

210. Prunus, species, Scudder, Bull. U. S. Geol. Surv. **6**, no. 2: 296.

211. Robinia, species, Scudder, Bull. U. S. Geol. Surv. **6**, no. 2: 296.

212. Sabal, species, Scudder, Bull. U. S. Geol. Surv. **6**: 297.

213. Spiraea, species, Scudder, Bull. U. S. Geol. Surv. **6**, no. 2: 296.

DESCRIPTIONS OF NEW SPECIES.

MUSCI.

Hypnum.

1. Hypnum Brownii, sp. nov. (Plate XII. figs. 4, 4a).

Stems creeping, forked or divided into nearly opposite branches; leaves ovate lanceolate, acuminate, concave.

This specimen is figured here to show the general habit of the plant. The leaves in most cases are indistinct and only the more solid stems are discernible. The plant seems to be analogous to the recent species *H. populeum*, Sw. The stems are slightly curved and the leaves on some portions are faintly visible. The leaves do not appear to be very closely imbricated. The tissues of mosses are very delicate, which explains why the fossil remains are so exceedingly rare. It is only in the later formation that the fossil forms are found.

CONIFERAE.

Pinus.

2. Pinus Hambachi, sp. nov. (Plate XIII. fig. 3).

Leaves in threes, long, narrow, pointed; stem rather thick; nerves obscure.

The specimen shows the end of a pine-branch with about 45 needles closely fascicled. The stem is 7 centimeters long and 3 to 4 millimeters in thickness and has a roughish appearance. The leaves average about 7 centimeters in length and a little less than a millimeter in width; their nervation is obscure. At the end of the stem are about 36 leaves so closely crowded together as to make all but the tips indistinct; but about one centimeter lower down there is a distinct bundle of nine leaves which spring from the surface of the stem. Upon closer examination it is shown that the leaves are fascicled; and that there appear to be three leaves to each sheath. I have not been able to find a description nor a figure of a pine which would characterize this specimen. The branch with the leaves has been well preserved, although from the nature of evergreens most specimens show only a few leaves. It is of course to be regretted that the fruit is not present. Two other species have been found at Florissant, *P. palaeostrobus*, Ett., and *P. Florissanti*, Lesqx., the latter having been determined by the cone.

MOREAE.

Ficus.

3. Ficus Haydenii, Lesqx. (Plate XII. fig. 3).

U. S. Geol. Rept. 7: 197. *Pl. XXX. fig. 1.* — Ann. Rep. U. S. Geol. Surv. 1872: 394.

Leaf subcoriaceous, entire, broadly lanceolate with a cordate base, tapering upward to a long acumen; petiole long; primary nerve strong near the base; secondary nerves thinner, curved in passing to the borders, camptodrome.

This leaf answers well to the description given by Lesquereux. The form of the leaf is well preserved with the exception of the apex, but enough is shown to indicate the acuminate nature.

The blade was probably 7.5–8.5 centimeters long, and has a width of 45 centimeters at the broadest portion near the base. The petiole is nearly 6 centimeters long. In the figures and description given by Lesquereux, the base curves slightly downward to the petiole. The present leaf is distinctly cordate. The secondary nerves alternate and are confluent to the midrib. They pass to the borders in gentle curves and anastomose in simple bows. Their angle of divergence is 40–50 degrees. The leaf has the form of a *Populus* but the venation is that of a *Ficus*. The description which Lesquereux gives was from a single specimen, and, even if the specimen here figured has a cordate base, the other characters are in favor of *F. Haydenii*. The specimen submitted to Lesquereux is from Black Buttes, Wyoming, and the species is considered very rare.

MALVACEAE.

Sterculia.

4. Sterculia Engleri, sp. nov. (Plate XIV. fig. 3).

Leaf coriaceous, comparatively large, palmately trilobate, triple-nerved; lobes cut nearly to the base, linear-oblong, entire, apparently acuminate; the middle lobe narrower than the lateral; base rounded; primary nerves distinct.

The specimen is a fragment, the upper portions of the lobes having been destroyed. The lateral lobes are 10 to 13 millimeters broad and the central lobe a little more than half as wide. Their apparent length was 7 or 8 centimeters. The lobes are almost straight and slightly narrowed toward the base which is rounded and decurrent to a thick petiole. The primary nerves, diverging at an angle of about 40°, arise from the top of the petiole. The secondary nerves are not visible. Only one other species has been found at Florissant. By the facies of this leaf, it might be compared with *S. Labrusca*, Ung. The main points of difference are, however, that the middle lobe of this leaf is the narrowest and that the lateral lobes are more nearly straight and longer than those of the leaves described and figured by Unger. The leaves of *S. lugubris*, described by Lesquereux in the "Flora of the Dakota Group," are also comparable with this leaf, but differ from it in their greater size, cuneate base and scythe-shaped lateral lobes.

ACERACEAE.

Acer.

5. Acer Florissanti, sp. nov. (Plate XI. fig. 1).

Leaf comparatively large, five-lobed, outline broadly oval; petiole long; middle lobe longest, broad and oblong; lateral lobes lanceolate; margin incised; base broad; basal nerves five, straight; secondary nerves distinct and nearly straight to the borders; veinlets anastomose, forming a fine net-work.

The markings of this leaf have been beautifully preserved. The blade is 10.5 centimeters long and about 8 centimeters broad. The middle lobe is oblong and dissected at the top. Of the lateral lobes, the upper are the largest. The central basal nerves, diverging at an angle of 30°–40°, are the most prominent. The secondary nerves are quite straight, and enter the points of the teeth on the margin. About forty-six species from the Tertiary formations of Europe have been described and referred to the different types of this genus, whereas in this country comparatively few fossil species have been found. This leaf by the facies and character of the venation is comparable with the recent species, *A. dasycarpum*, which it resembles in many respects.

6. Acer mysticum, sp. nov. (Plate XI. fig. 2).

The specimen which is here figured represents the fruit of an *Acer*. The fruit, oblong in shape, is nearly two centimeters long and six centimeters wide, and appears to contain an ovate seed. Along the back of the wing are four or five strong nerves. These give off nervilles which are more or less forked, and which cross the wing transversely nearly to the margin. The wing is somewhat wider below the middle. Since the seed was found by itself it cannot be safely classed with any of the known species.

ILICEAE.

Ilex.

7. Ilex rigida, sp. nov. (Plate XIV. fig. 2).

Leaves coriaceous, short-petioled, oblong; margin irregularly and acutely dentate; teeth beset with sharp spines; primary nerve very prominent; secondary nerves nearly straight, camptodrome; veinlets obscure.

The leaf is unlike those described by Lesquereux. It is about seven centimeters long and nearly two centimeters broad. The petiole is thick and short. The teeth are very sharp and larger in the middle of the leaf than at the ends; in some cases the spines can be distinctly seen. The midrib is the most conspicuous, and in the living species must have been very prominent and strong, giving rigidity to the leaf. The secondary nerves are firm and alternating, and branch out nearly at right angles from the primary. This species shows the main characteristics of the Iliceae. It differs from the known species in its oblong form and in the long and sharply pointed spines which project out nearly at right angles from the margin of the leaf.

RHAMNACEAE.

Zizyphus.

8. Zizyphus obtusa, sp. nov. (Plate XIII. fig. 1).

Leaf simple, small, subcoriaceous, ovate, somewhat unequal, triple-nerved; margin evenly serrated, the teeth fine and sharp, and smaller toward the apex; base round; apex obtusely pointed; petiole short and rather thick; basal nerves strong.

This leaf, although rather small, presents the characteristic nervation of the genus. The blade is 2 centimeters long and 1.3 centimeters broad. The middle nerve is thick and runs straight to the apex. The lateral, diverging at an angle of about 35°, curve gently along the margin. The secondary nerves which branch from the middle nerve diverge at a greater angle and anastomose in simple bows; those of the lateral nerves, toward the outer side of the leaf, seem to form a fine net-work which runs parallel with the margin of the leaf and sends off minute branches into the points of the teeth. The tertiary nerves are scarcely discernible. This leaf does not answer to the description of any of the five species enumerated by Lesquereux. It seems more closely allied to some form of *Z. Ungeri* of Heer.

Rhamnus.

9. Rhamnus ellipticus, sp. nov. (Plate XV. fig. 3).

Leaf simple, subcoriaceous, elliptical; margin entire; primary nerve thick and straight; secondary nerves close, numerous, nearly parallel, camptodrome; areolation quadrate.

The base of this leaf is wanting. The leaf is 2 centimeters broad and about 5 centimeters long. The secondary nerves, given off at an angle of 30°–40°, are nearly straight and sometimes incomplete. The leaf is analogous to that of *R. intermedius*, Lesqx., but the midrib is thinner and the secondary nerves in astomosing near the margin are more looped than those of the leaf described by Lesquereux.

JUGLANDACEAE.

Juglans.

10. Juglans Crossii, Knowlton. (Plate XIV. fig. 1).

Juglans denticulata, Heer. Lesqx. Ann. Rep. U. S. Geol. Surv. **1871**: 298.— Tert. Fl. **7**: 289. *Pl. LVIII. fig. 1.*

Leaves long-lanceolate, narrowed to a point and denticulate upwards; either rounded to the petiole or gradually attenuated to it (Lesquereux).

The specimen is fragmentary, but enough of the plant is present to show the necessary characteristics. Portions of two leaflets attached to the stem are shown in the fragment. One leaflet which seems to be terminal has a petiole whose length is three centimeters; most of this leaflet is wanting; its base is unequal and attenuated to the petiole. About half of the second leaflet is present. It was probably 10–12 centimeters long and 4 centimeters wide, lanceolate or elliptical, and narrowed to the point; it is denticulate and becomes narrower as it approaches the petiole which is four millimeters long. The base is unequal and round. The primary nerve is very strong; the secondary nerves are prominent, alternate, nearly straight, curving near the border, camptodrome, and are connected with the points of the teeth by distinct veinlets; the tertiary nerves are very oblique and, as in many recent species, nearly at right angles to the secondary; nervilles distinct. These leaves belong, undoubtedly, to the Juglandaceae. In the general character of the venation they agree with all the figures with which they were compared.

11. Juglans affinis, sp. nov. (Plate XIII. fig. 2).

Leaves lanceolate, acuminate, narrowed in a curve to a short petiole; border serrulate; lateral veins distant, alternate, parallel, curved in passing to the borders, ascending high along them in simple festoons, separated by short intermediate tertiary veins; areolation irregularly quadrate.

The above description corresponds almost entirely to that of *J. alkalina*, Lesqx., the only essential difference being in the kind of border. From the figure of *J. alkalina*, Lesqx. (Hayden's Rept. 7. *Pl. LXII. figs. 6–9*), it appears that the leaves must have had uniformly crenate margins, while the present species shows distinct serrations. The figure represents the only leaf of the kind that came to my notice. The leaf is nearly ten centimeters long and two and a half centimeters broad. The nervation is distinct. In consequence of the serrated border, the bows along the margin are connected with the teeth by fine nervilles.

ANACARDIACEAE.

Rhus.

12. Rhus rotundifolia, sp. nov. (Plate XII. fig. 2).

Leaf trifoliolate (or odd-pinnate); leaflets orbiculate, sessile; nervation looped; primary nerve strong; secondary nerves curved in passing to the borders, camptodrome.

Most of the plants belonging to this genus are characterized by a strong nervation which varies much according to the character of the leaf. In many cases where the margins of the leaves are entire the nervation is camptodrome. Plants with compound leaves are not uncommon. The specimen shows three leaflets, and although the leaf was probably trifoliolate, since the petiole has been broken off there remains the possibility that it might have been odd-pinnate. The leaflets are a little less than one centimeter long. The primary nerve is strong, especially toward the base. The secondary nerves, making an angle of 35°–65°, are confluent with the primary, mostly curved in passing to the borders, and camptodrome. The tertiary nerves are somewhat curved and form a polygonal net-work. This leaf is comparable with *R. villosa*, of Linnaeus.

EBENACEAE.

Diospyros.

13. Diospyros cuspidata, sp. nov. (Plate XII. fig. 1).

Calyx thick, coriaceous, four-lobed; lobes deeply cut, ovate-lanceolate, concave; peduncle comparatively long.

The lobes of the calyx, about one centimeter long and less than half as broad, are cut nearly to the base. Their nervation is indistinct. On account of the overlapping of one of the lobes by the opposite one, there appear to be but three divisions; on closer examination, however, the remains of the four sepals can be distinctly made out. In the general character the calyx might be compared with *Macreightia crassa*, Lesqx., although this species is described as having only three lobes. Two other species, *D. brachysepala*, Al. Br., and *D. Copeana*, Lesqx., represented by their leaves, have been found at Florissant.

SALICACEAE.

Populus.

14. Populus pyrifolia, sp. nov. (Plate XV. fig. 4).

Leaf membranaceous, ovate-lanceolate, very obtuse at the base, (apparently) crenulate, palmately seven-nerved; central, and upper lateral primary nerves strong and straight, at an acute angle of divergence, ascending high up along the borders and anastomosing in gentle curves.

This leaf was membranaceous in texture, and in the specimen the margin is poorly defined. Only at one place is the crenulate nature discernible. The margin near the base, however, is entire. The blade was probably 8 centimeters long and 5.3 centimeters broad at the widest part. The petiole is wanting. The primary nerves, diverging from each other at an angle of 25°–30°, are straight and strong toward the base, becoming much thinner as they approach the margin of the leaf. The secondary nerves are nearly parallel in their course through the blade.

On the lower side of the lateral primary nerves, gently curving branches are given off which anastomose with other branches near the margin. The nervilles are scarcely visible and are nearly at right angles to the principal nerves. The leaves of the poplar vary as to size, shape, margin and number of primary nerves, which accounts in great part for the many species that have been ascribed to the genus. From Florissant alone we have five other species, some of them also representatives of the European fossil flora.

Flores.

(Plate XV. figs. 1, 2.)

While looking over the collection of fossils, two flowers came to my notice, which I have not been able to classify with certainty.

Plate XV. figure 1, shows the remains of a flower that seems to have affinities with some of the Onagraceae. The calyx-tube prolonged beyond the ovary is 3.3 centimeters long and inflated above. Its divisions cannot be made out. The ovary is 1.3 centimeters long and three millimeters broad at the middle. The petals, five in number, are membranaceous, lanceolate and marked by a central nerve. The stigma is cylindrical and the course of the style through the tube can be traced nearly to the ovary. Most of the living Onagraceae with tubular calyces are 4-merous; a variation, however, might not be improbable.

Another flower, shown at Plate XV. fig. 2, has some of the characteristics of the Convolvulaceae. The corolla, apparently funnel-form or campanulate, has a five-sided border divided by slight clefts into five lobes. The sides of the borders are about two centimeters long. The venation has been beautifully preserved. Each lobe has a central straight nerve which passes to the apex. On either side of this are nerves which curve gently from the apex along the entire length of the lobe. Other prominent nerves mark the divisions between the lobes. These nerves before reaching the cleft in the margin generally divide and send branches toward the apices of the lobes on either side. The principal nerves generally anastomose near the margins. The nervilles are at right angles and the areolation is mostly quadrate.

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EXPLANATION OF ILLUSTRATIONS.

Plates XI–XV.

(All of the figures slightly reduced, unless otherwise noted.)

Plate XI. — 1, *Acer Florissanti.* 2, *A. mysticum.*

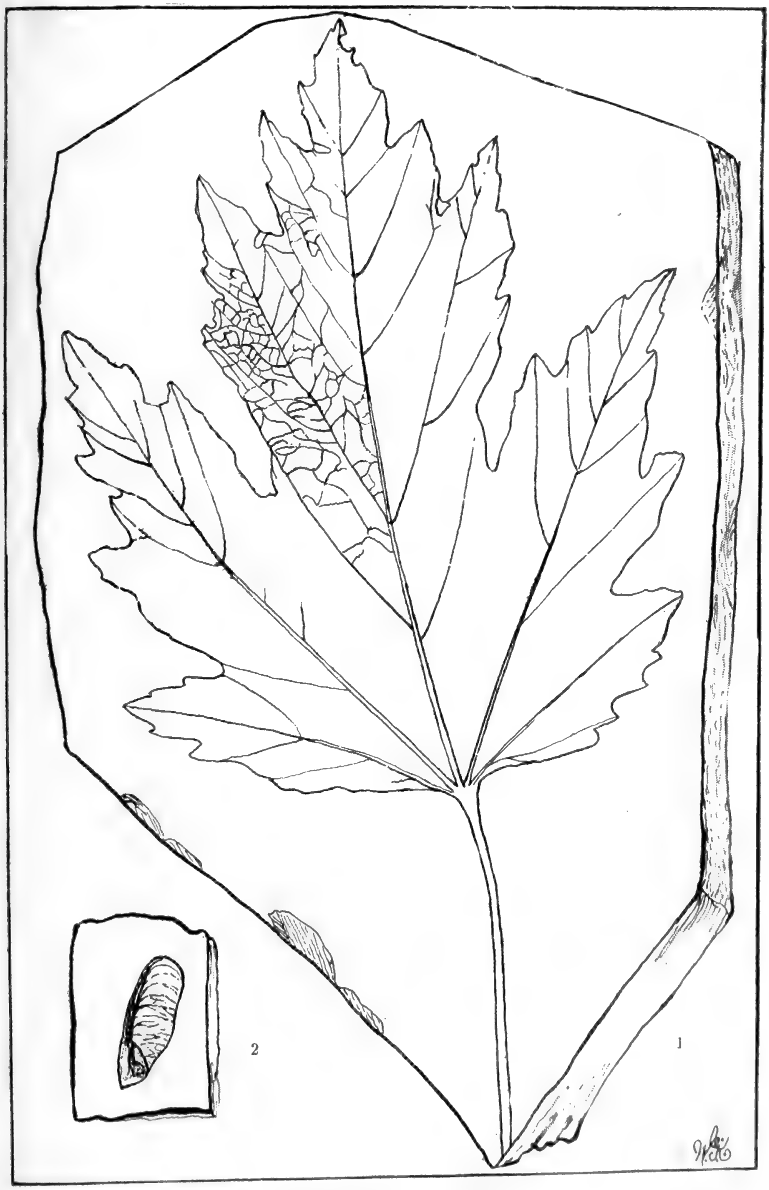
Plate XII. — 1, *Diospyros cuspidata.* 2, *Rhus rotundifolia.* 3, *Ficus Haydenii.* 4–4a, *Hypnum Brownii*, the latter enlarged.

Plate XIII. — 1, *Zizyphus obtusa.* 2, *Juglans affinis.* 3, *Pinus Hambachi.*

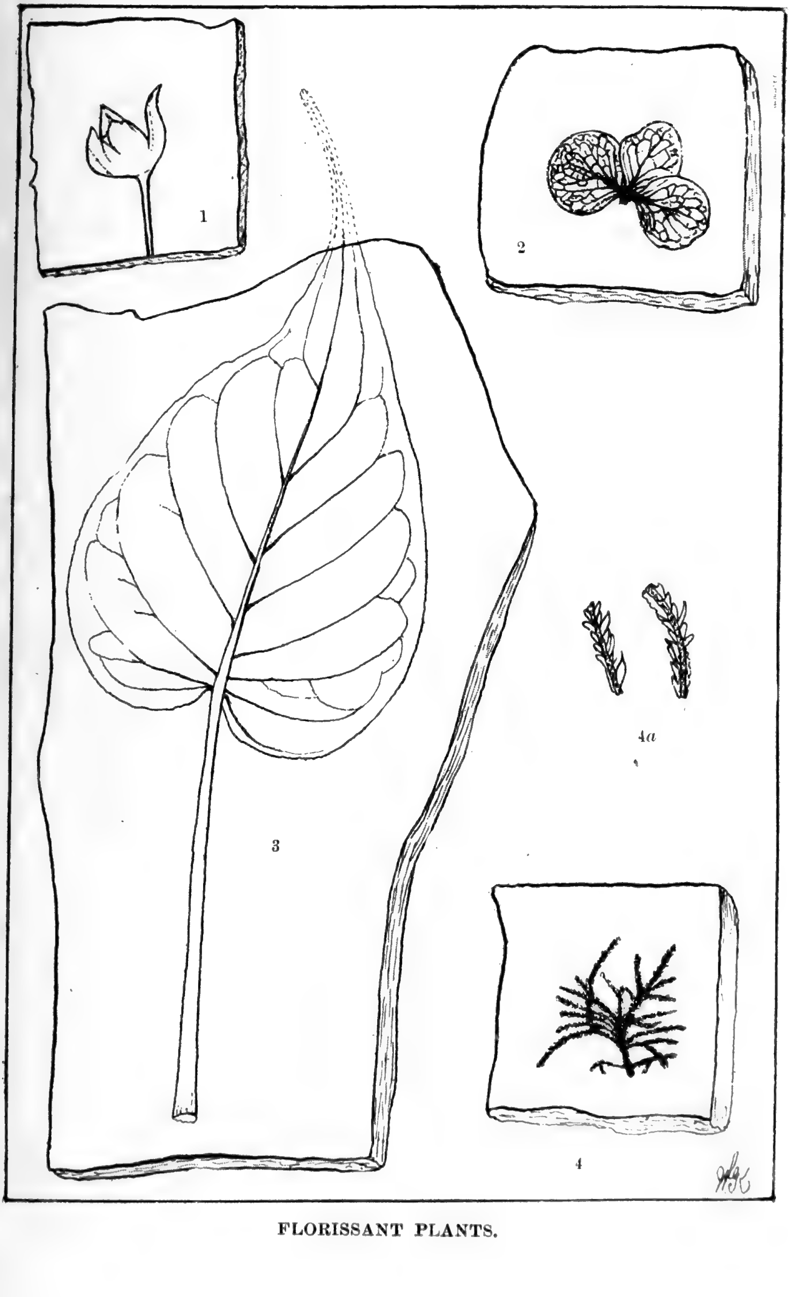
Plate XIV. — 1, *Juglans Crossii.* 2, *Ilex rigida.* 3. *Sterculia Engleri.*

Plate XV. — 1, Onagraceous? flower. 2, Convolvulaceous? flower. 3, *Rhamnus ellipticus.* 4, *Populus pyrifolia.*

Issued December 10, 1898.



FLORISSANT PLANTS.



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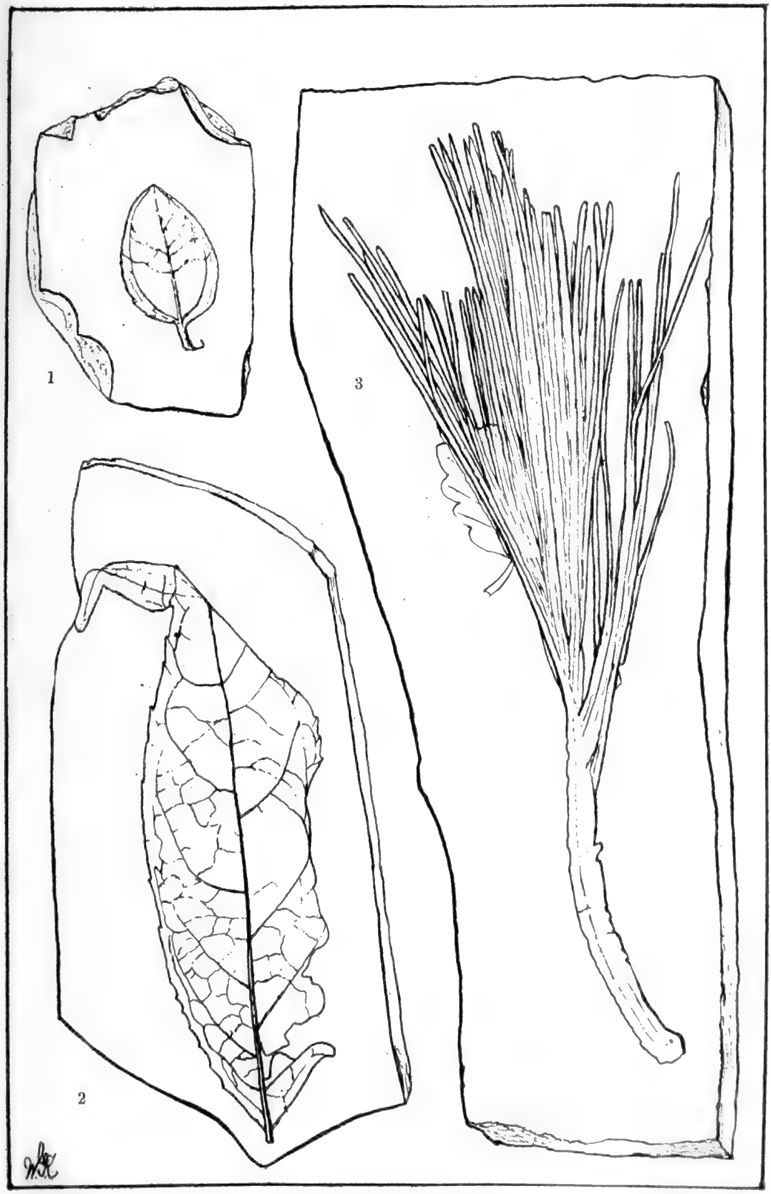

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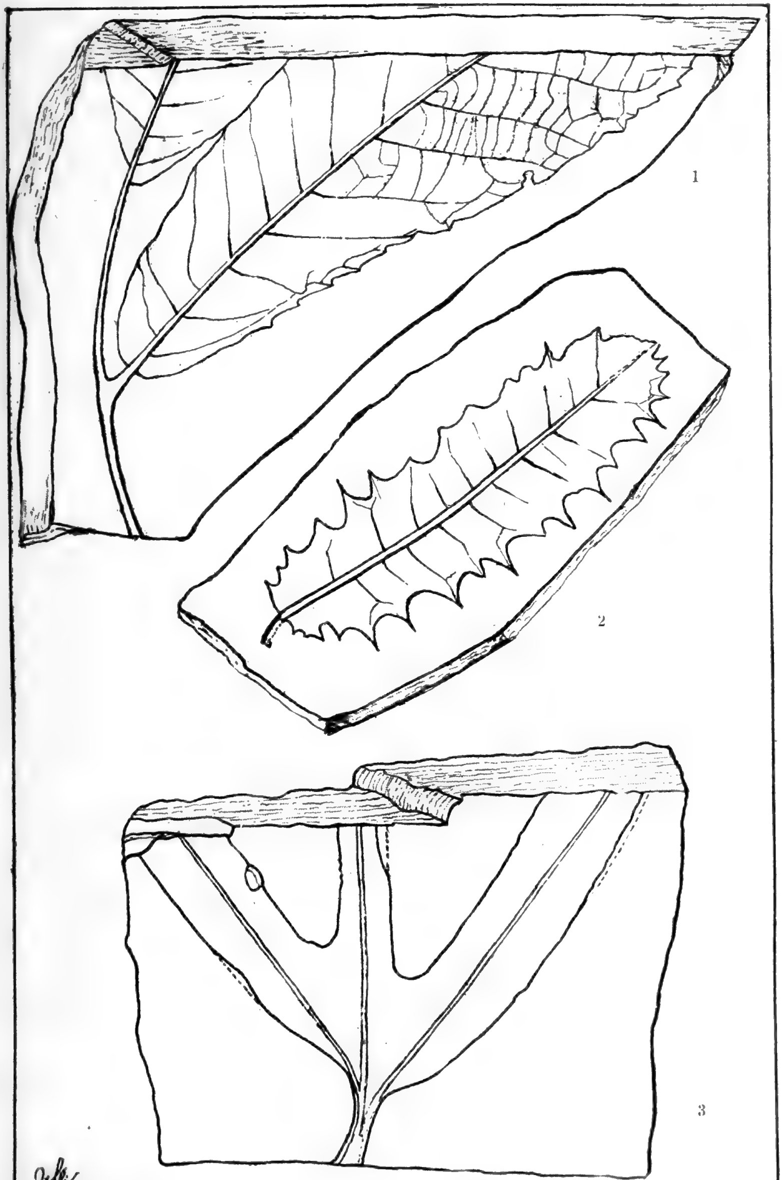

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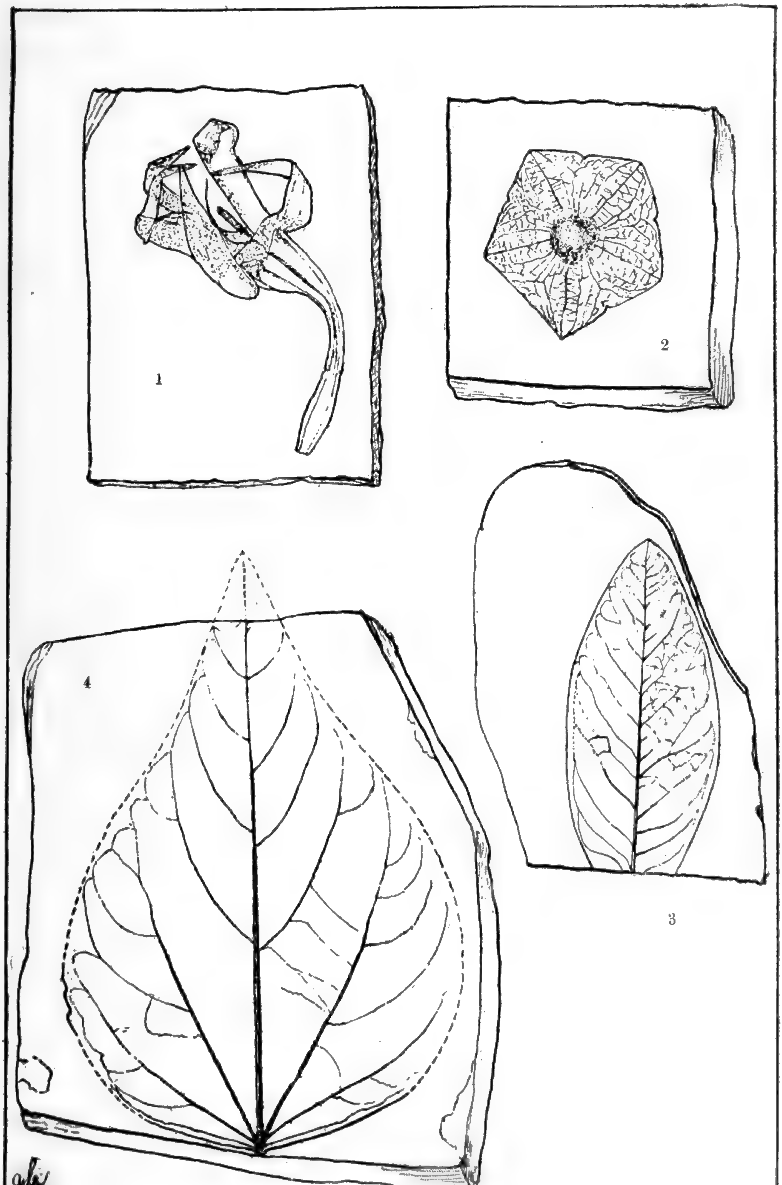

FLORISSANT PLANTS.

ON THE MODE OF DISSEMINATION OF USNEA BARBATA.*

HERMANN VON SCHRENK.

In many places along the North Atlantic coast one comes across tracts of forest in which a large number of the trees are covered with the common gray lichen, *Usnea barbata* and its varieties. This lichen often covers the trees entirely, giving them a sort of hoary appearance; where many such trees stand close together, especially if they happen to be conifers, the effect is truly a gloomy and somber one. The question has frequently occured why so many of the trees should be dead, and so universally covered with large masses of the lichen, and the notes following are to record some of the observations made in the Middle and North Atlantic States.

The species of *Usnea* are found all over the world, growing in nearly all cases on trees. Two forms may be distinguished. In the more common and well known, a central main stem of the thallus is firmly attached to the wood or bark, and forms a small clump or bush. The other type is that represented by such forms as *Usnea barbata dasypoga*, *Usnea longissima*, etc., in which the thallus as a unit has little or no connection with the branch or tree upon which it rests. These forms are truly epiphytic, and free from any suspicion of absorbing even small and insignificant quantities of food substances from their substratum. It is with this type that the following deals. The thallus consists of long threads, some as much as 20 inches in length, branching freely both

* Presented before the Academy of Science of St. Louis in preliminary form Dec. 21, 1896 (Trans. 7: lxi.), and, by title, Dec. 5, 1898.

dichotomously and by adventive branches, the latter standing usually at an angle of about 80°. Examined more minutely the thallus is found to consist of three layers, an external cortical layer, in which the hyphae are intricately entangled into a network of greater or less density, a middle layer with the gonidia, very much looser in texture, and a central or medullary layer in which the hyphae are parallel to the long axis of the thallus. Towards the tips both the main trunk and the branches rapidly decrease in diameter. As the thallus grows older, the cortical layer weakens and breaks in many places, exposing the medullary layer, with rings of cortex about it. This is specially marked when the thallus is wet and stretched. On the long hanging forms of *Usnea*, apothecia are very rarely found.

On Long Island and in Connecticut *Usnea barbata* (L.) var. *plicata*, Fr.,* is very common particularly on *Juniperus Virginiana* and *Pinus rigida*, while farther north in Massachusetts and Maine I have found *U. barbata* (L.) var. *dasypoga*, Fr., the more prevalent form, growing on the white spruce, *Picea alba*, and the balsam fir, *Abies balsamea*. This apparent predilection for the short-leaved Coniferae is probably due to the fact that the long threads are easily caught and held by branches with short leaves extending like brushes in all directions. Deciduous-leaved trees and the longer-leaved pines do not present such favorable supports; pieces of the lichen placed on such trees rarely become fixed, while those placed on *Juniperus* and *Abies* remained fast as long as they were kept under observation.

If one examines a tree covered by the lichen, one will find pieces varying from an inch in length to great masses on one and the same branch. The threads are rarely straight, but are bent and twisted among themselves, and wind in between and around the leaves and stem in a tangle which it is almost impossible to unravel. (See Pl. XVI.) This cannot be the result of growth, as the lichen grows so very slowly, and such tangles I have seen form in a few weeks. Nor is

* I am indebted to Miss Clara E. Cummings for the determination of these varieties.

it conceivable how the wind alone could cause the branches of the thallus to coil about the leaves and stem, and intertwine in the way they do. The explanation I believe lies in the fact that the branches are capable of a good deal of motion when moistened unequally. When a filament is torn away, its branches are always more or less bent and coiled. When moistened, the various branches at first either straighten out or coil more, depending upon the side which is wet first; after a few moments, the reverse motion takes place. The bending is due to the threads of the medullary layer which absorb water readily and increase some 10–15% in length, in the younger branches. If then a filament is caught by a branch like that of the spruce, it is first held simply by the diverging leaves. As it dries the various branches curve about in almost as many directions as there are branches, the tips describing arcs of 180° in many cases. When equal drying has taken place the branches endeavor to get back to their original position. Oftentimes they do, but far more frequently some other branch has crossed over, or a leaf has been pushed aside by a contracting filament, and in that way the branches are forced to assume different positions from the one first occupied. Repeated wetting and drying brings about more coiling and uncoiling, and ultimately such a tangle as is represented in the figure results. Many a filament lodges on a branch, coils and uncoils and is blown away again after a time, but on the whole more filaments are firmly secured shortly after being caught. I experimented with numerous pieces, which were placed on spruce branches, and carefully watched. After about four weeks the branches of the thallus were found firmly coiled about the leaves of the spruce. A few days later the whole piece might be off on another branch. (This was true only of single filaments, and did not occur with larger masses.)

The manner in which the lichen is disseminated is of interest. The wind is the chief factor concerned, although I have once seen birds using it for building their nest, and the lichen seemed to be in good condition. It is extremely probable that it is often carried by birds, but I have not seen any observations to this effect.* The wind sweeping through a tree catches hold of the long strands hanging from the branches and tears off pieces, which are carried to other trees. To find how and where the wind can tear the thallus various tests were made.† Several masses were weighed dry, and again after being soaked in distilled water. The latter was removed as completely as possible from the lichen by means of filter paper. Two trials showed: —

Weight of mass dry =	3.8 grs.	3.97 grs.
Weight soaked 12 hrs. =	13.3 grs.	11.5 grs.,

that is, the mass increased about three times in weight, which is probably below what it would be during a heavy rain. The threads are very elastic when wet, stretching 30–50% of their original length before breaking. The next test was to determine the longitudinal breaking strength. It was somewhat difficult to attach weights to the thread, and after some trials, wire hooks were inserted into loops tied into the ends of the threads, to one of which a scale pan with weights was attached. A number of threads were selected, as nearly as possible of the same diameter, but as this method is of course not very exact, the results can have only a relative value.

When dry the filaments broke at:	When soaked 12 hours:
198 gr.	28 gr.
109 gr.	23 gr.
144 gr.	27 gr.
130 gr.	25 gr.

Threads of *Usnea barbata*, var. *ceratina* gave these results: —

When dry:	When soaked 30 minutes:
224.6 gr.	53.5 gr.
266.0 gr.	43.0 gr.

* Schimper (Die epiphytische Vegetation Amerikas: 31) says that birds frequently use the strands of *Tillandsia usneoides* for building nests and thus spread the plant.

† Tests made with *Ramalina reticulata* are omitted as they have already been given by G. J. Peirce, On the mode of Dissemination and on the reticulations of *Ramalina reticulata*. Bot. Gazette **25** : 404. 1898.

These figures show that the individual threads are very much weaker when wet than when dry, and at the same time they are much heavier and more elastic. The action of the wind is liable to be most effective in times of storm, when it is also raining, in other words, when the thallus is wet and consequently most readily torn. It remained to be seen what wind velocities would suffice to bring about the tearing.

So far as I know no tests have ever been made to determine experimentally the strength or resisting power of any plant member in a stream of moving air. It is claimed that a hurricane may tear the leaf lamina, and we know it breaks branches and timber, but we do not know the actual strength of these organs. This has been due no doubt to an inability to measure the velocities of and pressure exerted by any given wind with any degree of accuracy. A piece of apparatus recently devised * enables one to measure with great exactness the velocity of, and pressure exerted by a moving current of air. Unfortunately for the tests made with *Usnea*, all the conditions existing during a rain-storm could not be brought about, so the results are somewhat higher than had been expected. Nevertheless they are given, as they bring out some interesting connections between longitudinal strength and the tearing force of the wind.

A pipe 8 inches in diameter and some 20 ft. long was attached to the exhaust of a fan inclosed in a box, and capable of several thousand revolutions per minute. By throttling the engine which turned the fan, the speed of the latter, and, correspondingly, the velocity of the air current produced by it, could be varied at will. Into the pipe a window was cut four feet from the end, and into this the cup for measuring the air current, as well as the lichen, was placed. The dry mass of *Usnea barbata* was first tried. In all the trials the long threads were tied to a vertical post in the pipe by means of silk threads. Repeated trials showed that wind velocities of 77 miles per hour were not sufficient to cause any pieces to fly off. The thallus was then soaked in water 30 minutes to 1 hour

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* Nipher, F. E. Trans. Acad. Sci. St. Louis 8: 1. 1898.

and tested similarly. The first pieces came flying off at velocities of about 50 miles per hour, and from then on large masses were torn away. By calculations it was found that the wind velocities represent the following pressures per square centimeter: —

49 miles	per	hour	= 2.738	gr.	per	sq.	cm.
52 "	"	"	= 3.425	"	"	"	"
56 "	"	"	= 3.930	"	"	"	"
70 "	"	"	= 6.105	"	"	"	"

It appears from this that a wind velocity of at least 50 miles an hour would be required to tear away pieces of the thallus. That this figure is much too high will be evident to one who knows how frequently the lichen is torn, and an inspection of the accompanying table recording wind velocities along the Atlantic and Pacific coast shows that the mean velocities nowhere approach this. The seeming error lies here. In the first place when the moist thallus was introduced into a stream of air, the drying action of the latter was felt immediately, so quickly, in fact, that after one minute's exposure the thallus was almost dry, *i. e.*, no longer in its weakest condition. In its native habitat no drying takes place, even with high wind velocity, because of the atmospheric moisture. Again, granting that a velocity of 50 miles tore the mass, it is not by any means necessary to assume such velocities for winds acting for periods longer than one minute. In this respect the experiment was a failure, that it gave only an extreme wind velocity. The relation found between tension and pressure was unexpected. The wind pressure per square centimeter at the period of greatest velocity, *i. e.*, 70 miles, was 6.1 gr., while at the tearing point it was but 3.+ grs. per sq. cm. The lowest breaking strength of the thallus threads however was found to be at least 23 gr.

TABLE OF WIND VELOCITIES FOR 1895.

The upper figure is the *mean* wind velocity, the lower the *maximum* velocity.

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Eastport, Me.........	12.3 66	14 72	11.5 42	11.3 60	9.5 48	7.7 30	6.8 28	7.9 29	8.9 32	11.9 44	12.1 46	15 54
Portland, Me.........	6.7 34	7.8 36	8.1 28	8.6 44	7.6 30	6.6 32	6.9 29	6.7 23	6.8 26	8.5 32	6.9 38	8.7 49
Northfield, Vt.........	8.1 40	9.1 36	10.2 45	8.9 40	9.0 37	7.0 86	7.8 27	7.5 33	7.7 35	9.9 37	8.4 38	9.2 49
Boston, Mass.........	11.1 40	13.5 47	12.6 37	10.8 43	10.7 31	8.8 30	9.4 30	9.3 29	9.8 33	12 46	11 41	13.2 50
Wood's Holl, Mass....	16.1 54	17.7 70	16.5 48	13.8 48	12.7 40	9.7 38	11.5 36	12.8 36	13 48	16.9 48	14.7 52	19 66
Block Island..........	17.7 56	19.2 66	16.1 47	14 46	13.7 36	11.2 38	10.2 43	11.4 32	12.8 38	16 48	16.6 54	20.5 68
New York, N. Y.......	10.6 36	13.1 43	14.4 64	14.5 54	12.1 42	9.7 40	11.1 45	10.8 62	11.3 48	14.7 48	13.4 42	16.2 73
Eureka, Cal..........	7.4 36	5.0 30	7.3 36	7.1 30	9.1 36	8.2 44	6.4 36	4.9 30	5.5 34	4.2 38	5.2 36	5.5 42
San Francisco, Cal....	9.5 44	7.1 31	9.6 36	10.7 35	13 36	14.3 40	15.5 38	13.8 36	11.5 35	8.7 36	7.7 36	7.3 34
Los Angeles, Cal......	3.9 18	3.4 9	3.6 20	3.8 24	4.0 26	8.7 15	3.2 14	2.8 12	3.3 14	3.1 14	3.1 12	3.4 18

This is worthy of note, and attention is called to this fact without attempting any explanation. Of the action of wind upon bodies offering resistance, either wholly or partially, to its passage, little is as yet known. Experimental data are entirely wanting from which one might formulate some law as to how long a wind of given velocity must act to produce a given result (either pressure or tension). Further it is not known what the nature of the longitudinal pull may be. It is suggested that the snapping motion of the filaments, like that of a snapping whip, may account for the efficiency of the lower tension actually found, for it is well known that it is easier to break a long body by snapping it than by direct pull. Further experiments with other plant members are in progress.

The experiments made with *Ramalina reticulata* by Peirce and myself indicate that this lichen is much like *Usnea barbata*. Wind velocities of less than fifty miles an hour tore off large pieces of *Ramalina*. Considering this relatively it would seem that lower wind velocities ought to tear *Ramalina*. Not having seen this lichen growing I cannot state this for it as I could for *Usnea*. A comparison of wind velocities on the Atlantic and Pacific coasts shows much higher average velocities on the Atlantic than on the Pacific. It seems that we have here a good instance of adaptation to their environment on the part of these two plants, representing similar ecologic factors in two widely separated regions. *Usnea*, growing where higher wind velocities were the rule, has a tensile strength somewhat above that necessary to resist the average wind velocities and greater than that of *Ramalina*, whose habitat is where lower average wind velocities are the rule. It would evidently not be advantageous to have a tensile strength so low that almost every wind would tear the thallus, for then the plant would not grow at all.

As pieces of the thallus grow very well when separated from the parent plant, this mode of dissemination is a very effective one. It resembles closely that of *Tillandsia usneoides*. Just as *Tillandsia* rarely forms good seed, so the hanging forms of *Usnea* rarely form apothecia, the vegetative method of propagation having become the prevailing one.

On walking through a forest of Conifers covered by *Usnea* one is struck by the fact that those portions of the trees where the lichen grows are either dead or dying. The temptation is a strong one to hold the lichen responsible for their death. The effect of lichens on trees has often been discussed. Lindau* mentions a number of species which seem to injure leaves and branches. "*Xanthoria parietina* grows around the leaves of pines like a cuff, and since the leaves are almost always dead, I am inclined to lay the greatest blame on the lichen, for it suffocated the leaves by covering the stomata." *Evernia Prunastri* attaches itself to lenticels on young twigs and blocks them. In general Lindau maintains that some lichens may injure trees by closing their air channels, but more often the appearance of lichens on trees is a sign that the latter are not healthy. Waite,† Waugh ‡ and others have discussed the effect of lichens on fruit trees. Ward § speaks of the shading effect of a tropical leaf lichen. But all these lichens are attached firmly to their substratum, so facts bearing upon their effect are not pertinent as far as *Usnea* is concerned. If the latter does any harm, it must be because it covers organs and deprives them of air and light. When large masses of this lichen become firmly attached to a branch they completely surround the leaves and hide them (Pl. XVI). When this happens in spring, as it frequently must, it is easily seen that leaves covered as are those in the figure, cannot assimilate and grow. The result is that they die and fall off. The terminal bud shares the same fate, and the next year that branch bears no leaves. If one takes away the mass of *Usnea* in August and September, the leaves covered by the lichen will almost always drop off. It is very noticeable that trees near the coast have more lichens on the sides toward the prevail-

* Lindau. Lichenologische Untersuchungen. Heft 1: 53. 1895.

† Waite, M. B. Experiments with Fungicides in the removal of lichens from pear trees. Journal of Mycology 7: 264–68.

‡ Waugh, F. A. 11th Rept. Vermont Exp. Station. — Also Meehan's Monthly 8: 178. 1898.

§ Ward, H. Marshall. On the Structure, development and life history of a tropical Epiphyllous Lichen, *Strigula complanata*. Trans. Linn. Soc. London. ii. Bot. 2: 87. 1884.

ing winds, and that these sides are usually dead. It is of course possible that that side died first for some reason and that the lichens then became attached. But it will be evident that in the case of *Usnea barbata* the selective reasons for becoming attached to a living branch are not the same as for lichens which become firmly attached. There can be no selective action on the part of the wind, which carries pieces alike to dead and living branches; and as has been said, such pieces are more likely to hold fast to living branches, because of the leaves. It does not seem probable that the mere fact of its being a healthy branch can determine whether the lichen shall live there or not. Only a large number of observations will definitely settle this point.

Issued December 17, 1898.

USNEA BARBATA, VAR. DASYPOGA, ON LIVING ABIES.

THE HISTOLOGY OF THE CARYOPSIS AND ENDOSPERM OF SOME GRASSES.*

L. H. PAMMEL.

Quite a number of botanists have given good accounts of the structure of the caryopsis of the economic grasses. Of the writers we may mention Harz,[1] Hunt,[2] Goodale,[3] Hackel,[4] Jumelle,[5] True,[6] Blyth,[7] Tschirch and Oesterle,[8] Van Tieghem,[9] Sachs,[10] Schenk,[11] Morris and Brown,[12] Trelease,[13] Harshberger,[14] Tschirch,[15] Bessey,[16] Nägeli,[17] Haberlandt,[18] and Zimmermann.[19]

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1 Harz. Landwirthschaftliche Samenkunde. Berlin. **2:** 1235. *pl. 135-201.*

2 Hunt, F. L. A Kernel of Indian Corn. Prairie Farmer. **58:** 196. — Rep. Board of Trustees of University of Ill. **13:** 196. 1886.

3 Goodale, G. L. Physiological Botany. 181.

4 Hackel, Edward. The True Grasses. (Eng. Trans. by F. Lamson-Scribner and Effie A. Southworth.) 24–25.

5 Jumelle. Sur la constitution du fruit d. graminées. Soc. d. sci. Nancy. Séance 23 Juillet, 1888. (According to Knoblauch. Just. Bot. Jahresb. **16:** 482. — Also abstr. Bull. Soc. bot. de France. **36.** Rev. Bibl. 5. 1889.)

6 True. On the Development of the Caryopsis. Bot. Gaz. **18:** 214. *pl. 24-26.*

7 Blyth. Foods, their compositions and uses. 216. (4th ed.)

8 Tschirch, A. und Oesterle, O. Anatomischer Atlas der Pharmakognosie und Nahrungsmittelkunde. 9. *pl. 41, 42, 43, 44, 45.* 11. *pl. 52, f. 5. pl. 53, f. 5-7.*

9 Ann. Sc. Nat. Bot. V. **15:** 246. 10 Sachs. Bot. Zeit. **1862:** 146.

11 Schenk. Anatomisch-physiologische Untersuchungen. Wien. 1872.

12 Jour. Royal Chem. Soc. **57:** 458.

13 Bull. Univ. of Wis. Agrl. Exp. Sta. 5: 7–10. *f. 1-3.* 1885.

14 Contr. Bot. Lab. Univ. Penn. **1:** 85. 1893.

15 Angewandte Pflanzenanatomie. Wien u. Leipzig. 548. *f. 1-614.* 1889.

16 The structure of the wheat grain. Bull. Neb. Agrl. Exp. Sta. 100–114. *f. 1-15,* [*16*]. 1894.

17 Die Stärkekörner. Pflanzenphys. Unt. Nägeli u. Cramer. Zürich. 2: 10 + 624. *10 pl.* 1858.

18 Physiologische Pflanzenatomie. 358, 211. (2nd ed.)

19 Ueber mechanische Einrichtungen zur Verbreitung der Samen und Früchte mit besonderer Berücksichtigung der Torsionserscheinungen. Inaugural-Dissertation. Pringsh. Jahrb. f. w. Bot. **12:** 542–577. *pl. 34-36.* 1881 Separate 41.

The most important contribution from a systematic standpoint was made by Harz,[1] who studied representatives of not only the economic grasses but many species of the indigenous European grasses.

The structure of the caryopsis is quite simple in all of the grasses. The pericarp consists of a usually thickened epidermal layer followed by thick-walled sclerotic parenchyma with pore canals. The poorly developed vascular elements occur within the parenchyma. In *Zea*, *Coix*, and *Secale* the pericarp is considerably developed. In *Cenchrus*, *Sporobolus*, and *Elymus* the pericarp is but slightly developed. In all of these except *Sporobolus* the protective features are preserved in the pericarp. The testa is more delicate and consists of several rows of thin-walled cells, longer than broad. The nucellus is not evident in most genera except in the groove, where it persists. True[2] has called attention to its occurrence in *Zea*, and Harz[3] in *Bromus*, *Festuca*, and *Brachypodium*. Tschirch & Oesterle also figure and describe it in several genera. It occurs in *Andropogon*, *Triticum*, *Hordeum* and *Secale*, though not well developed. In our species of *Elymus*, *Festuca*, and *Bromus* it is well developed and consists in part of a gelatinous layer. The endosperm is always well developed. The aleurone layer varies, consisting of a single row of cells in *Zea*, *Triticum*, *Cenchrus*, and *Elymus;* more than one row of cells in *Arrhenatherum avenaceum*, *Hordeum*, *Bouteloua* and some species of *Festuca*. These cells never contain starch but an abundance of a diastatic ferment. The cells following the aleurone are thinner-walled and contain some albuminoids, the amount varying in different species, a small quantity of fat and an abundance of starch. The starch occurs as simple or compound grains, simple in *Zea* where they are solidly packed. This is also true of *Panicum Crus-galli*, *Bouteloua hirsuta*, and *Setaria*. More loosely arranged in *Hordeum*, *Triticum*, *Secale* and *Andropogon*. The simple starch grains are frequently angular in *Zea* and *Panicum;* round or somewhat lens-shaped in *Hordeum*, *Andropogon*, and *Triticum*. Some

[1] Landwirthschaftliche Samenkunde.

[2] l. c.

[3] Linnea **43:** 1–30. — Samenkunde **2:** 1223.

of the larger grains in *Triticum*, *Hordeum*, and *Bromus* are plainly stratified. Compound grains occur in *Avena*, *Zizania*, *Arundinaria* and many other grasses. The embryo is joined to the endosperm by its columnar epithelium. The cells of the embryo are rich in albuminoids. In the region of the radicle and caulicle a few simple round starch grains occur in *Zea*.

Short descriptions follow of all the species here studied. As to the synonymy and arrangement I have followed Gray's Manual, 6th edition, for most of the American species. Otherwise Kew Index and Lamson-Scribner, Grasses of Tennessee. The material was obtained from the herbaria of the Iowa State College of Agriculture and Mechanic Arts, and the Missouri Botanical Garden. To Miss Charlotte M. King I am indebted for the faithful execution of my drawings.

ORYZEAE.

The genus *Oryza* has been described and figured by numerous investigators, Harz,[1] Tschirch & Oesterle,[2] Hanausek,[3] Moeller,[4] von Hohnel,[5] Tschirch,[6] Wiley[7] and other writers.

Oryza sativa, L. As in several other grasses the protective features are preserved in the glumes. Harz has studied these as well as the testa and pericarp. The pericarp consists of the epidermis and a compressed layer. The epidermal cells are longer than the underlying rows of cells. The latter layer is much compressed. The testa consists of one to two rows of cells with somewhat thickened walls. The structure of the nucellus can scarcely be made out. The nucellus is followed by the aleurone layer which consists of one to two rows of thin-walled cells. The endosperm makes up the bulk of the seed. It is smooth and somewhat vitreous, and the cells are densely filled with the separate components of the compound starch

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[1] l. c. 1276. *f. 171 (1,2,3,5)*. [2] Anatomischer Atlas. 9. *pl. 45*.

[3] Die Nahrungs- und Genussmittel aus dem Pflanzenreiche. Kassel. 45. 1884.

[4] Mikrospie der Nahrungs- und Genussmittel aus dem Pflanzenreiche. Berlin. 109. *f. 79–83*. 1886.

[5] Haberlandt. Wiss-prakt. Unters. 1: 151.

[6] Angewandte Pflanzenanatomie. 85. *f. 70*.

[7] Foods and food adulterations, etc. Bull. U. S. Dept. Agrl Div. Chem. 13: 1194. *pl. 52*.

grains. The component parts are angular. The grains are without an organic center. The large compound starch grains are not evident except when carefully treated, especially not in products that are manufactured from it, as rice flour. Acording to Harz[1] the structure of *Leersia oryzoides* is similar to that of *Oryza* (Pl.XVII. 4).

Zizania aquatica, L. The pericarp as well as the testa is colored brown, in some cases almost black. They are, however, but slightly developed. The pericarp consists of a single row or at most two rows of cells. These are not much longer than broad and rather thick-walled. The paricarp is followed by several rows of larger cells but somewhat thinner walled. The walls of the testa are thicker, the cells are smaller, they are likewise colored brown. In the mature specimens there is no evidence of remnants of the nucellus except in a few places where it is strongly compressed. The aleurone layer consists of a single row of somewhat tabular cells. The vitreous starch layer contains large compound and some simple grains (Pl. XVII. 1).

MAYDEAE.

Two genera were studied, *Euchlaena* and *Zea*.

Zea Mays, L. I have in another connection discussed the structure of *Zea*.[2] The pericarp consists of thick-walled epidermal cells followed by a layer of variable thicknesses, the walls of which are greatly thickened, with radiating pore canals. The testa is insignificant, the walls are thinner than in pericarp. Remnants of the nucellus may be distinguished in some parts of the seed. This is followed by the endosperm. The aleurone cells are smaller, very different from those underlying it. The starch cells following the aleurone are closely packed and filled with angular starch grains (Pl. XIX. 11).

Euchlaena mexicana, Schrad. Teosinte is closely related to *Zea*.[3] Its structure is very different from that of *Zea*.[4] The

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[1] l. c. 1280. *f. 171, IV–VI.*

[2] Comparative anatomy of the corn caryopsis. Proc. Ia. Acad. Sci. **5:** 199–203. *f. 5–10.* 1897.— Contr. Bot. Dep. Ia. State Coll. Agr. & Mechanic Arts. 10.

[3] Harshberger, Garden & Forest **9:** 522, considers our corn to have been derived from *Zea canina* Watson and *Euchlaena mexicana*.

[4] Harz, l. c. 1249, has given a brief account of its structure.

smooth coriaceous hard glumes consist of from four to six rows of thick-walled sclerotic cells with a comparatively small cell-cavity and radiating pore canals. The pericarp and testa are but slightly developed because the protective features occur in the glumes. The cells of the pericarp are elongated and thin-walled. The walls of the testa are thicker, the layer being much compressed. The cells of the aleurone layer are large and consist of a single row. The starch cells are densely packed with polygonal starch grains as in *Zea*. After dissolution of the starch grains protein substances remain (Pl. XVII. 3).

ANDROPOGONEAE.

Various forms of *Sorghum vulgare* have been described and figured by Harz.[1]

Sorghum vulgare, Pers. In chicken corn (*Andropogon Sorghum* var. *cernuum*) the cells of the epidermis are thick-walled, followed by a somewhat similar layer below. Underneath this occur elongated parenchyma cells with a narrow cavity. The inner portion of the pericarp consists of thin-walled cells which appear as circles somewhat widely separated. The testa consists of a single row of large thin-walled cells. The aleurone layer is usually of a single row of cells much smaller than the starch cells. The latter contain nearly spherical grains which are not closely packed. An abundance of protein grains occurs in the starch layer.

I was compelled to use this species, since I was unable to get good seed in the herbaria consulted of any of our northern species. Nor was I able to get good seed in the field (Pl. XIX. 4).

PANICEAE.

Of this tribe I have studied *Panicum glabrum*, *Panicum Crus-galli*, *Setaria italica* and *Cenchrus tribuloides*. Harz[2] has given us a good account of *Panicum miliaceum* and *Panicum sanguinale*, L.

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[1] l. c. 1249. *f. 163, 164.*

[2] l. c. 1255. *f. 165, 166, XX–XXII.*—*P. sanguinale*, l. c. 1258. *XXIII–XXV.*

Panicum glabrum, Gaud. Shows but slight development of the pericarp and testa. The epidermal cells of the former are smaller than the underlying rows of cells of the wall of the ovary. The testa is reduced to a single layer of cells, longer than broad. The aleurone layer is filled with protein grains. The starch cells of the endosperm are large and densely packed with polygonal grains.

The walls of the ovary of *Panicum miliaceum*, L. are similar to those of *Panicum glabrum* except that they are wider.

The testa is much compressed and consists of several rows of small cells. The cells of the aleurone layer are small, somewhat longer than broad. The cells of the starch layer are similar to those of the last species (Pl. XVIII. 7).

Panicum Crus-galli, L. The adherent glumes in this species consist of several rows of parenchyma cells. The inner portion, of one row of thick-walled sclerotic cells with pore canals. The cells of the pericarp and testa are much as in other species, thin-walled and compressed. The protective features are preserved in the coriaceous glumes. The starch and aleurone layers similar to those of *P. glabrum* (Pl. XIX. 2).

Setaria italica, Kunth. The colorless smooth pericarp is but slightly thickened and consists of three to four rows of elongated cells. These in colored seeds contain the pigment. The testa is but slightly developed.[1]

The cells of the aleurone layer are not much longer than broad, densely filled with protein grains. The abutting starch cells are much smaller than the remaining ones. All of the cells are densely filled with polygonal starch grains as in *Panicum* (Pl. XVIII. 5).

Cenchrus tribuloides, L. The only other member of this tribe studied has a greater development of the pericarp. It is divided into two portions. The cells of outer portion thicker-walled and shorter; the inner of elongated, thick-walled and somewhat fusiform cells. The testa consists of one to two rows of thin-walled cells, much compressed but expanding on the addition of chloral hydrate. The aleurone cells are much larger than in *Panicum* and *Setaria*, thick-walled,

[1] Harz. l. c. 1260. — *S. glauca,* l. c. 1259. — *S. verticillata,* l. c. 1260. — *S. viridis,* l. c. 1260. — *S. germanica,* l. c. 1261.

densely filled with protein grains. The starch cells with rather thick walls. The starch grains are large and more loosely arranged. This is a deviation from the type usually found in the tribe *Paniceae* (Pl. XIX. 1).

PHALARIDEAE.

Harz[1] has studied *Phalaris canariensis*, and *P. arundinacea* as well as *Anthoxanthum* and *Hierochloe*. The brown pericarp of Canary grass has rather thick-walled epidermal cells. The underlying cells are thin-walled, and tangentially elongated. The testa likewise consists of elongated thin-walled cells. The cells of the aleurone layer are rather large, in a single row. The starch cells are large, containing large compound grains.

Phalaris arundinacea, L. It is extremely difficult to cut good sections of Reed Canary grass. The brown pericarp is not greatly developed. The epidermal cells are elongated tangentially, thick-walled. The underlying layer of the pericarp also consists of thick-walled cells. The walls of the testa are thin and the layer is much compressed. The aleurone layer consists of a single row of cells somewhat variable in size, usually as long as wide. The cells of the starch layer are large, densely filled with large compound starch grains. The individual elements are angular. The central part of each separate grain is marked by a nucleus (Pl. XVII. 9).

AGROSTIDEAE.

A number of species and genera of the tribe *Agrostideae* have been studied by Harz,[2] especially *Calamagrostis*, *Agrostis*, *Alopecurus*, *Phleum* and *Stipa*.

Aristida ramosissima, Engelm. In this Triple-awned grass the pericarp is but slightly developed. The outer portion consists of thick-walled rectangular cells. But a single layer of cells of the testa is evident. They

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[1] l. c. — *P. canariensis*, 1273. *f. 170. I–IV.* — *P. arundinacea*, 1274. *f. 170. V–VIII.*

[2] l. c. — *Calamagrostis*, 1264. — *Agrostis*, 1262. — *Alopecurus*, 1268. — *Phleum*, 1270. — *Stipa*, 1282. — *Ammophila*, 1267.

are elongated, thick-walled, with a small lumen. The aleurone cells are nearly as long as broad, densely filled with protein grains. The cells of the starch layer are much larger than in the aleurone, and densely filled with compound starch grains. The individual components are more or less angular owing to pressure. The compound grains are not nearly so large as in *Avena* and *Zizania.* The grains contain from two to a dozen component parts. The embryo contains a blackish-blue pigment (Pl. XVIII. 8).

Stipa, L. The genus *Stipa* has been studied by Harz[1] and Zimmermann,[2] also in a very general way by Darwin.[3]

Stipa robusta, Scribner. The outer part of the caryopsis consists of rather thick-walled tangentially elongated cells. The surface of the nearly colorless epidermal cells is slightly uneven, having somewhat the appearance of little circular rings. The underlying three or four rows of cells are very much compressed. They are likewise colorless. The cells are tangentially alongated. The testa is dark in color and consists of two differentiated layers. In a cross section, the outer row is seen to consist of small thick-walled cells. Minute longitudinal canals are evident, with a very narrow cell cavity; tangentially these cells are elongated, slightly curved, with prominent cross striae. The layers below are much compressed and consist of tangentially elongated cells, brown in color. Harz states that remnants of the nucellus remain in *Stipa pennata.* The aleurone layer consists of a single row of cells somewhat longer than broad. The remaining portion of the endosperm consists of starch cells somewhat variable in size, densely filled with small simple grains. The individual elements are angular because of pressure. *Stipa pennata* according to Harz has both simple and compound grains. If the grains of *S. robusta* are compound, the component parts are easily separated. The adherent glume consists of thick-walled sclerotic elements with pore canals, in longitudinal view elongated, tapering at both ends (Pl. XVII. 13).

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[1] l. c. 1282. [2] l. c.

[3] On the hygroscopic mechanism by which certain seeds are enabled to bury themselves. Jour. Linn. Soc. 1: 151–167. *pl. 23.*

Of the *Phleoideae* I have studied *Phleum*. A short account of the anatomy of this and several related grasses is given by Harz,[1] who states that anatomically it has the same structure as *Alopecurus* and *Agrostis*. In *Alopecurus* the starch grains are simple and compound, in *Phleum* compound or small and simple. The aleurone grains are solidly packed in *Phleum* and more abundant than in *Alopecurus*.

Phleum pratense, L. The testa and pericarp are dark-colored. The epidermal cells are thin-walled, elongated, sometimes slightly irregular. The testa consists of several rows of thick-walled, dark brown cells much longer than broad. The aleurone layer consists of a single row of cells relatively thin-walled, somewhat variable in size, solidly packed with aleurone grains. The nucellus is very evident as a remnant in some places. The cells of this layer are thick-walled, clear and colorless. The starch cells are much larger than the aleurone, and contain somewhat angular starch grains, probably compound. Protein matter present (Pl. XVII. 12).

Sporobolus, R. Br. Of the *Agrosteae* only *Sporobolus cryptandrus*, Gray, was studied, but Harz has given accounts of other representatives of this sub-tribe, among them *Agrostis alba*, *Calamagrostis*, several species, and *Ammophila*. There appears to be considerable difference between *Ammophila* and *Agrostis*. In *Ammophila* there is considerable development of both testa and pericarp, while both are only slightly developed in *Agrostis*.

Sporobolus cryptandrus, A. Gray. The outer row of cells of the caryopsis of *Sporobolus* is mucilaginous. The cells of the testa are thicker-walled, much compressed. It is difficult to distinguish the testa from the inner portion of the pericarp. The aleurone layer consists of a single row of thin-walled narrow cells followed by the much larger cells of the starch layer, the cells of which are densely filled with simple grains (Pl. XIX. 7).

AVENEAE.

Good accounts of the structure of several species of the tribe *Aveneae* are given by Harz.[2] The same writer[3] figures

[1] l. c. 1270. [2] l. c. 1320. *f. 193.* [3] l. c., *Deschampsia*, 1311.

and describes *Deschampsia*, *Aira*[1] and *Arrhenatherum*.[2] In some of these genera the nucellus is very evident. In all, the starch grains are compound. The genus *Avena* has been described by a large number of writers, Tschirch und Oesterle,[3] Moeller,[4] Hanausek,[5] Klencke,[6] and Barnes.[7]

In *Arrhenatherum avenaceum*, Beauv. the pericarp consists of elongated thin-walled cells with a large cell cavity. This is followed by a compressed layer of several rows of cells somewhat difficult to make out in most sections. The testa consists of several rows of thicker walled cells followed by the remnants of the nucellus. The outer portions of the endosperm consist of the aleurone layer of two rows of cells densely filled with protein grains. In the outer portions of the starch layer, the compound starch grains are less abundant than in the interior. The compound grains are large, with the component parts decidedly angular (Pl. XVII. 2).

Avena sativa, L. In common oats the caryopsis is slightly hairy. The large epidermal cells are thick-walled, slightly irregular on the surface, followed by several rows of thick-walled cells in a general way much like the epidermal cells. The testa consists of a much compressed layer mostly of two rows of thick-walled cells; remnants of the nucellus evident. The aleurone layer of the endosperm consists of one or two rows of cells; the outer portion of the starch cells contains less starch than the inner. The starch consists of large compound grains, the component parts five- to six-sided (Pl. XIX. 6, A. B.).

CHLORIDEAE.

Of the *Chlorideae* the writer has studied only *Bouteloua hirsuta*, Lag. The pericarp and testa are but slightly developed. The epidermal cells of the caryopsis are thick-walled, elongated. Two or three rows of compressed thick-walled cells follow the epidermis. The testa consists of two rows

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1 *Aira*, 1312.
2 *Arrhenatherum*, 1308.
3 Anatomischer Atlas. 9. *pl. 44*.
4 Nahrungs- und Genussmittel. 105, 160.
5 Die Nahrungs- und Genussmittel aus dem Pflanzenreiche. 36.
6 Lexikon der Verfälschungen. 240.
7 Plant Life. 301. *f. 346*.

of thinner-walled cells; the aleurone layer, of two to three rows of nearly isodiametric cells, followed by the starch cells. The starch cells are densely packed with polygonal grains, apparently simple. Harz has described and figured the structure of *Cynodon Dactylon*, with compound starch grains. The same writer places *Nardus stricta* in this tribe, but Bentham and Hooker exclude it. The *Nardus* has compound starch grains like *Cynodon* (Pl. XIX. 5).

FESTUCEAE.

The tribe *Festuceae* includes quite a large number of our prominent forage plants. The microscopic structure of members of this tribe has been studied by Harz. He describes the following genera: *Phragmites*,[1] *Arundo*,[2] *Melica*,[3] *Dactylis*,[4] *Poa*,[5] *Glyceria*,[6] *Festuca*,[7] *Bromus*,[8] *Brachypodium*,[9] *Scolochloa*,[10] and *Koeleria*.[11]

Phragmites communis, Trin. Has a thin pericarp of three to six rows of pigment cells. The testa consists of loosely arranged parenchyma cells. Remnants of the nucellus sparing and much compressed. The aleurone layer of a single row of cells, quadratic or tangentially elongated. Its contents, as well as those of the embryo, are colored red with potash, according to Harz. Small simple and compound starch grains present (Pl. XIX. 8).

Koeleria sp. The epidermal cells of *Koeleria* are elongated, the lateral walls with irregular outlines. The underlying portions of the pericarp consist of thin-walled cells. The testa is made up of one to two rows of nearly colorless, tangentially elongated cells. Remnants of the nucellus present but very much compressed or in some parts of the seed more evident. The outer membrane of the aleurone layer thick walled, inner part thinner. The layer consists of a single row of cells. The starch cells contain compound grains, the component parts are polygonal. In addition to the com-

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[1] l. c. 1338.
[2] l. c. 1339.
[3] l. c. 1333.
[4] l. c. 1299.
[5] l. c. 1284.
[6] l. c. 1300. *f. 178, II, III.*
[7] l. c. 1290. *f. 178, I.*
[8] l. c. 1223.
[9] l. c. 1232.
[10] l. c. 1337.
[11] l. c. 1336.

pound grains there are numerous simple round grains of larger size (Pl. XIX. 10).

Dactylis glomerata, L. The epidermal part of the caryopsis consists of rather thin-walled somewhat elongated cells followed by a layer of thick-walled elongated cells. These cells do not differ essentially from those of the testa. The cells of the testa are smaller and similar. The remnants of the nucellus are colorless and more or less mucilaginous. The aleurone layer consists of a single row of cells, usually a little longer than wide. The starch grains relatively large and apparently simple, oval or round. Harz states that they are slightly attached together (Pl. XVII. 11).

Poa pratensis, L. Harz, in addition to his account of the anatomical structure of *Poa nemoralis*, gives the anatomy of common blue-grass, but only with reference to the structure of the starch grains. The account of the endosperm, the caryopsis and testa of *Poa sudetica* is more complete. In *Poa pratensis* the pericarp and testa are both but slightly developed. The epidermal cells of the caryopsis are elongated, rather thick-walled. According to Harz the outer part of the caryopsis is followed by several thin-walled underlying parenchyma layers. The testa consists of two rows of tabular cells with considerably thicker walls than the epidermis. The nucellus is very much compressed, and not evident except upon treatment with chloral hydrate. The aleurone layer consists of one row of cells, or occasionally doubled; the cells are longer than broad. The cells of the starch layer are much larger than the aleurone cells, the vitreous starch grains compound and simple. The individual elements are somewhat angular or polygonal (Pl. XVII. 10).

Festuca Shortii, Wood. Several species of the genus *Festuca* were studied by Harz. The microscopic structure of *Festuca* shows that it is very closely allied to *Bromus*. The adhering palet as shown in cross section consists of thick-walled epidermal cells followed by two or three rows of thinner-walled parenchyma cells. The cells of the outer row of the caryopsis are thin-walled and in cross section mostly a little longer than broad. This is followed by several rows of somewhat similar cells, also thin-walled. The nucellus is very conspicuous, consisting of an outer row or sometimes several rows of very thick-walled cells; the walls are mucilaginous and on the addition of water are rapidly converted into mucilage, showing the remnant of the primary cell wall. The inner part of the nucellus consists of thick-walled cells, elongated and much compressed. I am not certain that the thick-walled gelatinous layer is a part of the nucellus, but it appears to me, however, that it belongs to the nucellus rather than the testa, although Harz refers it to the testa. Not having studied the development of this species, it is difficult to say whether it belongs to the nucellus or to the testa. The aleurone layer consists usually of a single row of cells although in places there are two rows. The cells are nearly as broad as long in cross section. They are much smaller than the underlying starch cells. The starch cells are much thicker-walled than in other species of grasses previously described in this paper. The reserve material is in part cellulose. The cavity is quite densely filled with small and simple starch grains (Pl. XIX. 3).

Glyceria aquatica, Smith. *Glyceria aquatica* and *G. fluitans* were figured and described by Harz.[1] I had considerable difficulty in obtaining good sections of the former. In *Glyceria aquatica* the outer cells of the caryopsis are tabular in shape, the inner walls being considerably thickened. The underlying parenchyma cells are tangentially elongated. The outer row of the cells of the testa small. Harz states that it consists of one row of enormously enlarged and thick-walled cells. The remnants of the nucellus present. The cells of the aleurone layer much the same as in *Glyceria aquatica*, a little longer than broad. The starch cells are large, densely filled with compound starch grains. *Glyceria fluitans* has essentially the same structure as *G. aquatica* excepting that the cells of the inner portion of the testa are much smaller (Pl. XVII. 7). In *Glyceria aquatica* the testa as well as the pericarp is but slightly developed. The outer part of the caryopsis is dark in color. The epidermal cells are comparatively thin-walled, elongated and somewhat tabular. The underlying layer

[1] l. c., *G. aquatica*, 1300. *f. 178, II.* — *G. fluitans*, 1300. *f. 178, III.*

consists of a single row of cells, in some cases considerably elongated, followed by the vitreous starch layer. The cells are densely filled with larger compound starch grains, the component parts are five-sided (Pl. XVII. 8).

Bromus ciliatus, L., var. *purgans*, A. Gray. In speaking of the genus *Festuca* the statement was made that it is closely allied to *Bromus*. Both genera are very closely allied to *Brachypodium* from an anatomical standpoint. I have elsewhere indicated that several species of the genera *Bromus* and *Brachypodium* were studied by Harz.[1] In *Bromus* the palet partially adheres to the caryopsis especially in the groove. The epidermis and the underlying cells of the palet are thin-walled and toward the groove very much smaller. The pericarp consists of dark-colored cells somewhat longer than broad, relatively thin-walled, of one or two rows. The cells of the testa are thicker-walled and dark brown. The outer portion of the nucellus consists of large thick-walled stratified cells. On the addition of water the thick walls expand and are partially converted into mucilage. In the groove the nucellus increases from one to a dozen rows of cells; the cells are likewise thick-walled but they are not stratified as in the outer layer. The inner part of the nucellus is compressed. The aleurone layer consists of a single row of relatively large cells. The starch cells are very much larger than the aleurone and thick-walled as in *Festuca*. They contain a large number of simple starch grains, and an abundance of protein elements (Pl. XVIII. 3).

HORDEAE.

This tribe contains the economic genera *Hordeum*, *Triticum*, and *Secale*. All works treating of the economic food products have usually given short accounts of the structure of the fruit, testa and endosperm. I shall refer to some of these papers under each genus.

Triticum, L. There are excellent accounts of the structure of *Triticum* by Harz, Tschirch & Oesterle,[2] Hanausek,[3]

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[1] l. c. 1232. *f. 158.* [2] l. c. [3] l. c.

Moeller,[1] Koernicke,[2] Hoehnel,[3] Marek,[4] Wittmack,[5] and Bessey.[6] Harz has given us an excellent account of the different forms of *Triticum: T. vulgare, T. polonicum, T. turgidum,* and *T. durum*, as well as the different forms of *Triticum Spelta.*

Triticum Spelta, L., and *T. monococcum.* These differ anatomically in a very marked degree, according to Harz, chiefly in the epidermal cells of the caryopsis, and the nucellus. In *T. Spelta* the epidermis consists of tangentially elongated cells, the internal walls greatly thickened. The underlying cells are somewhat thinner-walled. The pericarp is much more simple in its structure than in *T. vulgare.* My studies do not entirely agree with those given by Harz. The testa consists of elongated cells not markedly different from those of the pericarp. The aleurone consists of a single layer of large cells densely filled with aleurone grains. The remainder of the endosperm usually of larger cells containing the spherical or elliptical starch grains. The cells of the first row of the starch layer are smaller. The remnants of the nucellus evident only in the groove of the seed. Here a dozen or more rows of small thick-walled, colorless cells occur, which soon disappear on either side (Pl. XVIII. 1. — *Triticum sativum*, Pl. XIX. 9).

Triticum monococcum, L. This does not differ so essentially from *T. Spelta* except in the structure of the epidermal cells of the caryopsis. The exterior walls of the epidermal cells are greatly thickened and larger than in *T. Spelta.* The caryopsis consists of two rows of cells. The cells of the testa are longer, thick-walled and colored brown. The nucellus of this species as in *Triticum Spelta.* The aleurone of one row of large cells, and occasionally a second row of smaller cells, longer than broad, densely filled with

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[1] l. c.

[2] Koernicke and Werner, Handbuch des Getreidebaues. Bonn. 1885.

[3] Vergleichende Untersuchungen d. Epidermis d. Gramineen Spelzen u. deren Beziehung zum Hypoderma. Haberlandt's Wiss. Prakt. Untersuchungen auf d. Gebiete d. Pflanzenbaues **1:** 168.

[4] Das Saatgut u. dessen Einfluss auf Menge u. Güte d. Ernte. Wien. 193. *f. 174.* 1875.

[5] Ueber die Erkennung d. Verfälschung von Roggenmehl mit Weizenmehl. Sitzb. Ver. Prov. Brandenburg **24:** 4-8. (Abstract Hanausek, Bot. Centralbl. **18:** 91-92. 1883.)

[6] l. c.

aleurone grains. The starch layer variable; as a rule, however, the starch cells are much larger than the aleurone. In some cases the first row of cells smaller, and these carry more protein than the cells below. The starch grains are large, elliptical or spherical, extremely variable in size. These cells also have an abundance of aleurone (Pl. XVIII. 2).

Secale cereale, L. An excellent account of the structure of this fruit will be found in the works of Harz, Tschirch & Oesterle,[1] Tietschert,[2] Gregory[3] and other writers on economic food products.

The pericarp consists of tangentially elongated epidermal cells with large cell cavities. The outer wall is thickened as well as the inner, the lateral walls thinner. Harz states that there is an important distinction between *Secale* and *Triticum;* a somewhat analogous structure, however, occurs in the spelts. The epidermal layer is followed by smaller thin-walled parenchyma cells. The layer next to these parenchyma cells is frequently composed of thick-walled porous cells with pore canals. These cells not evident except in mature fruits. The testa is but slightly developed and consists of comparatively small cells frequently colored brown. The nucellus occurs as a remnant especially in the groove, where the cells are thick-walled and somewhat gelatinous. The endosperm resembles that of wheat. The aleurone layer consists of a single layer of cells. The exterior walls are greatly thickened. The cells of the starch layer large, containing a large number of round or elliptical starch grains, extremely variable in size. The starch grains on the whole are larger than those of the genus *Triticum* (Pl. XVIII. 6).

Hordeum vulgare, L. The structure of *Hordeum* has been given by Tschirch & Oesterle,[4] Morris & Brown,[5] Harz,[6] Kudelka,[7] and others.

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[1] l. c. [2] Keimungsversuche mit Roggen und Raps. 104. *f. 1*.

[3] Die Membranverdickungen der sogenannten Querzellen in der Fruchtwand des Roggens. Fünfstück, Beiträge zur wiss. Bot. **2:** 165–168.

[4] Anatomischer Atlas der Pharmakognosie und Nahrungsmittelkunde. 9: 181. *pl. 41*.

[5] Jour. Roy. Chem. Soc. **57:** 458. [6] l. c. 1159. *f. 136*.

[7] Ueber d. Entw. u. d. Bau d. Frucht- u. Samenschalen unserer Cerealien Inaug. Diss. Berlin. 1875.

The adhering palet consists of several rows of thick-walled cells. The epidermal cells are longer and somewhat thicker-walled. The cells below are also thick-walled, provided with pore canals. In places the epidermal cells develop into a short trichome. Underneath the thick-walled cells occur several rows of thin-walled irregular parenchyma cells. The pericarp follows. It consists of several rows of thick-walled translucent cells, the cavity being very much reduced. The testa is colored brown. The cells are tangentially elongated and the cell-walls are thinner. The nucellus is very much reduced excepting in the groove, where it occurs as thick-walled cells. The endosperm differs in a very marked degree from either that of *Triticum* or *Secale*, especially the aleurone, which consists of three to four or exceptionally more rows of cells. The starch cells are much larger and contain large spherical or elliptical starch grains, accompanied by numerous smaller ones. Small protein grains abundant (Pl. XVIII. 9).

Hordeum jubatum, L. The grain in *Hordeum jubatum* is adherent to the palet. The epidermis consists of thick-walled tangentially elongated cells, at least most of the cells are longer than broad. In part the cells are developed into short conical trichomes. The underlying cells are thick-walled with prominent pore canals. The remainder of the adhering palet consists of thin-walled cells much longer than broad. The pericarp as well as the testa is but slightly developed. In some cases the underlying parenchyma cells are not clearly defined, or at least not evident until the specimens are treated with chloral hydrate. The blackish pigment is largely found in the internal part of the palet. Some of the pigment also occurs in the pericarp and the aleurone layer. The pericarp consists of one or two rows of rather thin-walled tangentially elongated cells. The testa is reduced to a single layer of cells somewhat longer than broad. The nucellus is nearly absent except in the groove. It consists of a single row of thin-walled, colorless, compressed cells. In the groove several rows of cells occur. On either side of the groove these soon disappear. The aleurone in the specimens studied is made up of a single row of cells. The cells of the starch layer are large and filled with round or elliptical grains. The starch cells are larger than those of the aleurone. The starch grains are mostly round or somewhat elliptical (Pl. XVII. 6).

Elymus canadensis, L. In *Elymus canadensis* and otber species of the genus the grain is adherent to the glume. The outer part does not differ essentially from that of the genus *Hordeum* except that the walls of the epidermal cells are not so thick. The underlying cells are thick-walled as in the genus *Hordeum*. The pericarp consists of thick-walled tangentially elongated cells with a very small cell-cavity. The inner portion of the pericarp consists of a row of thinner-walled cells. The testa consists of a layer of thin-walled cells. The remnants of the nucellus much compressed, and on the addition of chloral hydrate appear as a translucent colorless layer with greatly thickened walls; the cell-cavity much reduced. The aleurone consists of a single layer of cells. The cells of the starch layer are much larger than the aleurone and filled with spherical or elliptical starch grains (Pl. XVIII. 4).

BAMBUSEAE.

Arundinaria macrosperma, Michx. The large grains of this species are free. The epidermal cells of the pericarp are thick-walled and roughened. The lateral walls are much thinner than the exterior. The external wall is plainly stratified. The cells are marked with prominent pore canals. The underlying layer consists of two to three rows of very similar cells except that the walls are less thickened. The internal part of the pericarp consists of one to two rows of thick-walled cells with a very narrow cell-cavity. The testa consists of thinner-walled cells of slightly brownish color. The aleurone consists of several rows of thick-walled cells. The large starch cells contain relatively large compound grains. The individual elements are five- to six-sided (Pl. XVII. 5).

SYNOPSIS OF ANATOMICAL CHARACTERS FOR TRIBES.

The following synopsis of the tribes studied by myself, including those studied by Harz, gives the chief anatomical characters of the fruit and seed.

Oryzeae.

Starch grains compound. Aleurone cells small, one or two rows. Testa but slightly developed. *Oryza, Zizania, Leersia.*

Maydeae.

Starch grains simple, solidly packed. Aleurone cells a single row. Testa and pericarp but slightly developed in *Euchlaena, Coix.* In *Zea,* pericarp greatly developed, testa less so.

Andropogoneae.

Starch grains simple. *Andropogon Ischaemum, Sorghum vulgare.* Aleurone a single layer of cells. Testa with large cells, especially in our common forms of *Sorghum.*

Paniceae.

Starch grains simple, solidly packed in *Panicum, Setaria;* more loosely in *Cenchrus.* Aleurone cells a single row. Testa and pericarp slightly developed.

Phalarideae.

Starch grains compound. Aleurone cells a single row. Testa and pericarp but slightly developed. *Phalaris, Anthoxanthum, Hierochloe.*

Agrostideae.

Starch grains compound in *Agrostis, Calamagrostis, Ammophila, Alopecurus, Phleum? Stipa?* in *Aristida,* simple. Pericarp and testa slightly developed, except *Ammophila.* Aleurone cells a single row.

Aveneae.

Compound starch grains, *Avena, Arrhenatherum, Aira, Holcus, Deschampsia, Trisetum.* Aleurone cells one or more rows. Pericarp and testa variable, usually not greatly developed.

Chlorideae.

Compound starch grains, *Cynodon. Bouteloua?* Aleurone cells one or more rows. Testa and pericarp but slightly developed.

Festuceae.

Compound starch grains, *Phragmites, Arundo, Melica, Poa, Glyceria, Festuca.— Scholochloa, Koeleria,* in part. Simple, *Dactylis, Bromus, Brachypodium, Festuca, Scholochloa.* Aleurone cells one or more rows. Testa and pericarp not greatly developed. Nucellus pronounced in *Bromus, Festuca, Brachypodium.*

Hordeae.

Simple grains, *Hordeum, Secale, Triticum, Elymus, Agropyron, Aegilops.* Compound, *Lolium, Nardus.* Aleurone usually a single row. Nucellus very evident in *Lolium, Elymus.* Testa and pericarp not well developed.

Bambuseae.

Starch grains compound. Aleurone layer of more than one row of cells. Pericarp well developed. Testa less. *Arundinaria.*

SUMMARY.

Structurally there are wide differences between the tribes of the order, very marked in some closely allied genera. The pericarp is well developed in such genera as *Zea*, *Arundinaria*, and fairly well in *Triticum*, *Secale*, *Hordeum* and *Avena*. The testa is but slightly developed in most cases, notably so in *Festuca*, *Panicum glabrum*, *Aristida* and *Oryza sativa*, the protective features being provided for by the glumes surrounding the fruit, or the wall of the ovary. The nucellus is never entirely absent, especially in the groove. It is usually much compressed. In the genera *Festuca* and *Bromus*, the cells are large, thick-walled and mucilaginous, and no doubt act as reserve food. The aleurone layer is variable. It is never absent. Of one row of cells in *Triticum*, *Zea*, *Zizania*. The cells are very small in *Panicum Crus-galli*, *Aristida*, *Setaria italica*. Of more than one row of cells in *Avena*, *Arrhenatherum*, *Festuca*, *Hordeum vulgare*. The starch cells differ in size and contain small spherical or elliptical grains in *Sorghum vulgare* and *Cenchrus tribuloides*. Large spherical or somewhat elliptical grains occur in *Triticum* and *Hordeum*, accompanied by numerous smaller ones. Small five or six-sided grains in *Panicum Crus-galli*, *Zea Mays*, *Euchlaena mexicana*. This applies in general to the tribe *Maydeae* and *Paniceae*. *Cenchrus* is, however, an exception to the rule. Compound starch grains occur in *Zizania*, *Oryza*, *Avena*, *Arrhenatherum*, *Glyceria*, *Poa*, *Phalaris* and *Arundinaria;* most grasses appear to have compound grains. The endosperm always contains protein, though much reduced in the starch cells, except in the aleurone layer, where no starch occurs. The starch cells next to the endosperm contain more protein than the interior of the endosperm. Fat is also present in small amounts. The compound starch grains of *Nardus* in the tribe *Hordeae* are somewhat anomalous.

EXPLANATION OF ILLUSTRATIONS.

PLATES XVII–XIX.

Sections of *Phragmites communis*, *Oryza sativa*, *Glyceria fluitans*, *Arundinaria macrosperma*, *Arrhenatherum*, *Stipa robusta*, *Phleum pratense*, and *Dactylis glomerata*, were drawn to the same scale with Grunow ocular and Schrauer No. 7 objective. All other figures drawn to the same scale with Abbé camera, Leitz objective No. 7 and ocular No. 3. The two systems nearly correspond.

Different parts of the caryopsis lettered uniformly unless otherwise stated. P = pericarp. t = testa. a = aleurone. s = endosperm with starch grains. cc = cuticle. n = nucellus. gl = glume. scl = sclerotic cells. en = endosperm. e = embryo. ep = epidermis. All figures original wash drawings made from author's sketches by Miss King and uniformly reduced in engraving.

Plate XVII. — I, *Zizania aquatica:* large compound starch grains in endosperm; aleurone layer a single row of cells. — II, *Arrhenatherum avenaceum:* aleurone layer of two rows of cells; starch grains compound.— III, *Euchlaena mexicana:* starch grains solidly packed together.— IV, *Oryza sativa:* compound starch grains; aleurone layer a single row of cells. — V, *Arundinaria macrosperma:* aleurone layer of more than one row of cells; compound starch grains in endosperm. — VI, *Hordeum jubatum:* thick-walled sclerotic cells of glume with short trichomes above the caryopsis; *c*, the nucellus only a remnant. — VII, *Glyceria fluitans:* with compound starch grains. — VIII, *G. aquatica:* with compound starch grains.— IX, *Phalaris arundinacea:* testa and pericarp but slightly developed; large compound starch grains. — X, *Poa pratensis:* large compound starch grains in endosperm. — XI, *Dactylis glomerata:* aleurone layer a single row of cells; starch grains simple. — XII, *Phleum pratense:* lower figure, general view cross section of seed with embryo in position.— XIII, *Stipa robusta:* thick-walled cells *x* above testa and several rows of thinner-walled cells underneath the fertile glume; longitudinal view of sclerotic cells of glume shown in upper figure; cross section to the left with an enlarged view at *t'*.

Plate XVIII. — I, *Triticum Spelta:* simple round or elliptical starch grains in endosperm. — II, *T. monococcum:* remnants of nucellus present. — III, *Bromus ciliatus* var. *purgans:* nucellus with thick-walled stratified cells. — IV, *Elymus canadensis:* cells of glume thick-walled, also those of nucellus, but the latter not stratified. — V, *Setaria italica:* starch grains compressed; aleurone cells small.— VI, *Secale cereale:* large spherical or somewhat elliptical starch grains; nucellus a single row of cells; *p'*, porous thickened walls of pericarp.— VII, *Panicum glabrum:* aleurone cells small; starch grains solidly packed.— VIII, *Aristida ramosissima:* compound starch grains in endosperm. — IX, *Hordeum vulgare:* thick-walled cells of glume with pore canals; aleurone cells of more than one row.

Plate XIX. — I, *Cenchrus tribuloides:* aleurone layer of a single row of cells; starch grains spherical or elliptical. — II, *Panicum Crus-galli:* glume adjacent to pericarp with lower layer of cells thick-walled, showing pore canals; single row of cells to aleurone layer; starch grains solidly packed.— III, *Festuca Shortii:* aleurone layer of one or more rows, cells of the nucellus thick-walled; starch grains apparently compound, showing individual component parts separated. — IV, *Sorghum vulgare* var. *communis* (*Andropogon Sorghum* var.): small aleurone cells; simple spherical or elliptical starch grains. — V, *Bouteloua hirsuta:* aleurone layer of several rows of cells; starch grains solidly packed. — VI, *Avena sativa:* pericarp with irregular cells on surface; the minute down of "seed;" *Aa* single row of cells to aleurone layer; in *B* more than one row; starch grains compound. — VII, *Sporobolus cryptandrus:* pericarp, *c*, mucilaginous; aleurone cells small, of a single row; *U*, a more magnified portion of the pericarp and testa after the addition of chloral hydrate. — VIII, *Phragmites communis:* aleurone layer of a single row of cells, starch grains solidly packed. — IX, *Triticum vulgare:* aleurone layer a single row of cells, cell-walls of testa and pericarp thick-walled; longitudinal view of pericarp cells shown at *b;* starch grains large, spherical. — X, *Koeleria* sp.: nucellus a single row of cells, also the aleurone layer; starch grains large, compound, testa of a single row of cells. — XI, *Zea Mays:* nucellus a single row of cells; pericarp much more developed than testa.

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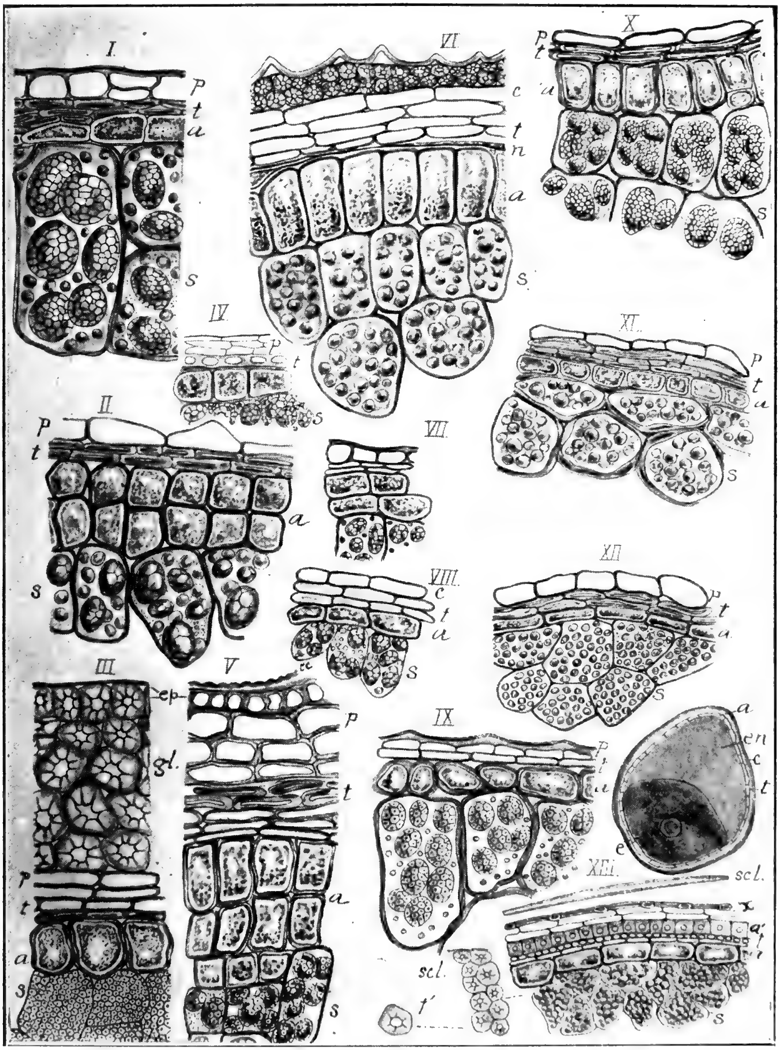
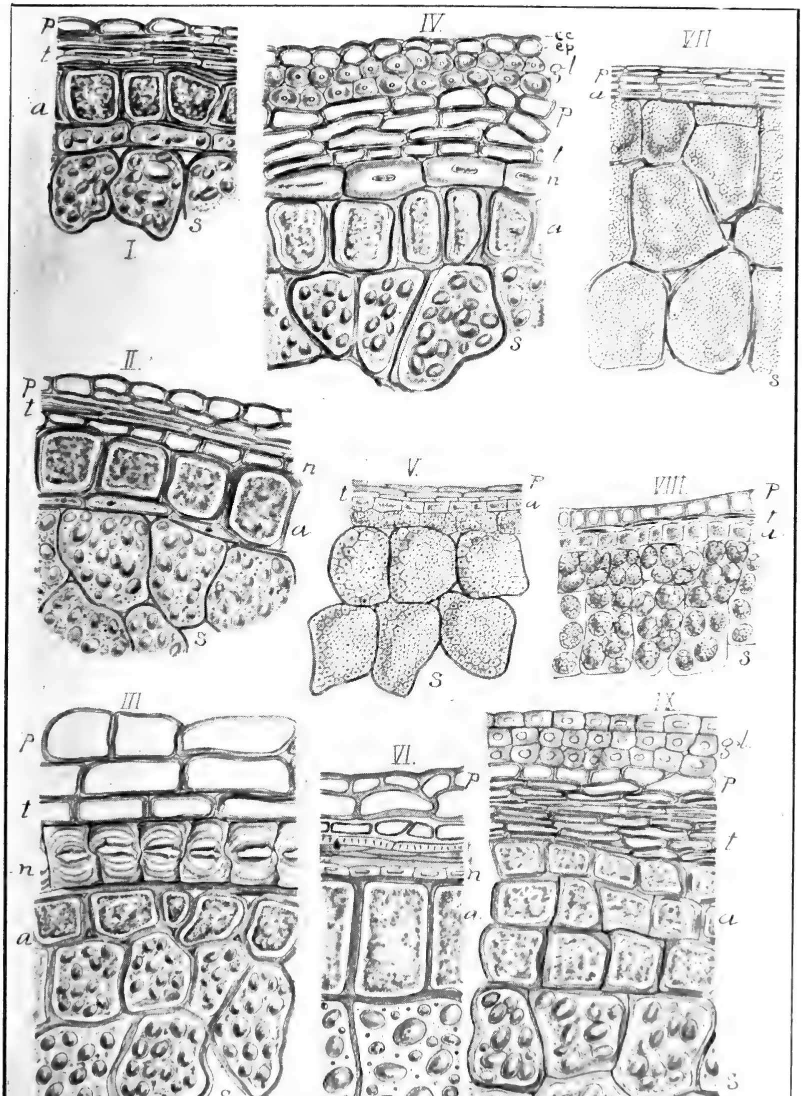


CARYOPSIS AND ENDOSPERM OF GRASSES.



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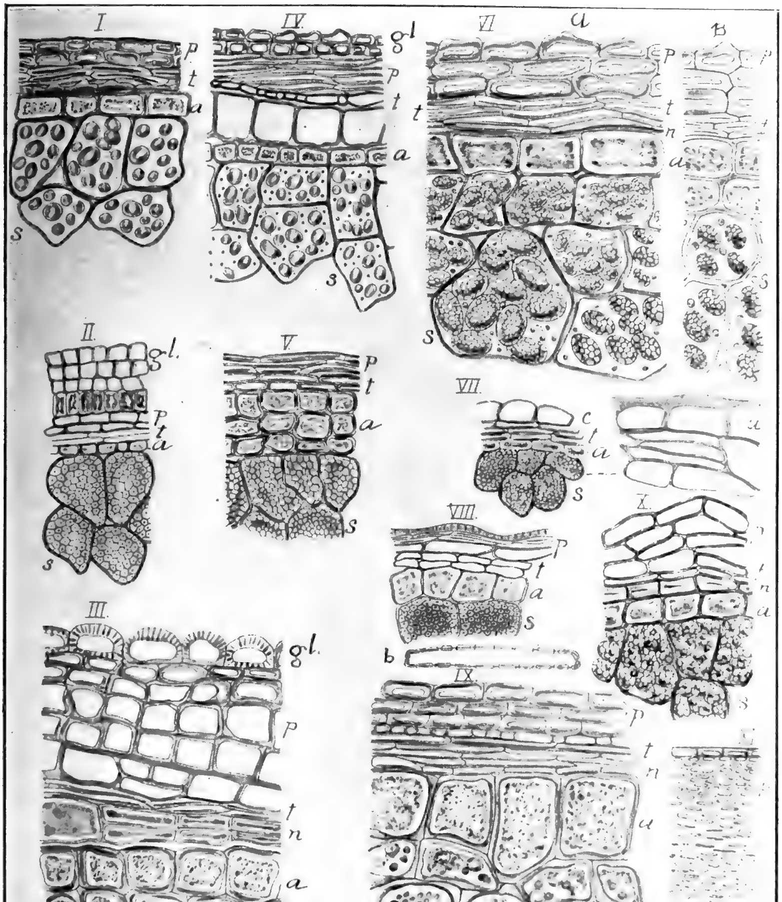

CARYOPSIS AND ENDOSPERM OF GRASSES.

LIST OF AUTHORS.

GENERAL INDEX.

INDEX TO GENERA.

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