PROCEEDINGS

OF THE

Iowa Academy of Science

FOR 1921

VOLUME XXVIII

THIRTY-FIFTH ANNUAL SESSION, HELD AT
INDIANOLA, APRIL 29 AND 30, 1921

PUBLISHED BY
THE STATE OF IOWA
DES MOINES

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THE TORCH PRESS
CEDAR RAPIDS
IOWA

IOWA ACADEMY OF SCIENCE

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Todd, J. E.	1888-1889
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Nutting, C. C. (2 terms)	1890-1892
Pammel, L. H.	1892-1893
Andrews, L. W.	1893-1894
Norris, H. W. (1 term)	1894-1896
Hall, T. P.	1896
Franklin, W. S.	1896-1897
Macbride, T. H.	1897-1898
Hendrixson, W. S.	1898-1899
Norton, W. H.	1899-1900
Veblen, A. A.	1900-1901
Summers, H. E.	1901-1902
Fink, Bruce	1902-1904
Shimek, B.	1904-1905
Arey, M. F.	1905-1906
Bates, C. O.	1906-1907
Tilton, John L.	1907-1908
Calvin, Samuel	1908-1909
Almy, Frank F.	1909-1910
Houser, Gilbert L.	1910-1911
Begeman, L.	1911-1912
Bennett, A. A.	1912-1913
Kinney, C. N.	1913-1914
Conard, Henry S.	1914-1915
Kelly, Harry M.	1915-1916
Stewart, George W.	1916-1917
Ross, L. S.	1917-1918
Beyer, S. W.	1918-1919
Stephens, T. C.	1919-1920
Knight, Nicholas	1920-1921

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*Lees, Jas. H...........................Geological Survey, Des Moines
Norton, W. H...........................Cornell College, Mount Vernon
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Ricker, Maurice........U. S. Public Health Service, Washington, D. C.
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*Woodward, S. M..............................State University, Iowa City

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Smith, Donald M. .... State College, Ames
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Torrance, D. Merrill .... Van Horne
Treganza, J. A. .... Britt
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*Williams, Noel J...Milford
Willson, L. H...................................State College, Ames
Wilson, Ben H................Iowa Wesleyan College, Mount Pleasant
Young, Paul A.............................Coe College, Cedar Rapids

TITLES OF PAPERS PRESENTED

Zoology

Botany

Child Welfare

Iowa Section, Mathematical Association of America

PROCEEDINGS OF THE THIRTY-FIFTH ANNUAL SESSION

Held at Indianola, April 29 and 30, 1921

The meetings of the thirty-fifth annual session were held at Simpson College on Friday and Saturday, April 29 and 30, 1921. President Knight called the opening meeting to order at 1:30 p. m. in the auditorium of the new Administration Building. After the business session the President gave his address on "American Science." At the conclusion of this meeting the Academy adjourned to meet as sections. At 5 o'clock the members were given an enjoyable auto ride through the courtesy of the Indianola Chamber of Commerce and at 6 o'clock the sections met at group dinners. At 8 o'clock the Academy was addressed by Dr. J. Paul Goode of the University of Chicago on "America as a World Power." Following this meeting President and Mrs. Hillman received the members of the Academy in the parlors of the Administration Building. The executive committee held a meeting at which the proposed revision of the Constitution was discussed and approved.

On Saturday morning the sections met at 9 o'clock to complete their programs and at 10:30 the Academy convened to hear the discussion by Doctors Baldwin and Stecher on Child Welfare Research and that by Dr. Morehouse on Nova Cygni, No. 3. At 11 o'clock the business session was convened and the first order of business was the reading and passage of the revised constitution. Invitations for the next meeting were received from Penn College and Drake University. The Executive Committee later accepted the invitation of Drake. After the reception of committee reports and the election of officers under the new constitution the Academy adjourned.

REPORT OF THE SECRETARY

Members of the Academy:

Probably the activity of a society such as ours may be gauged primarily by the interest in and attendance upon its meetings and also by the number and quality of the papers presented before its membership. Of almost equal importance, however, is the thought given by the society's members to its welfare throughout the year and their interest in attracting new members into its fellowship. It is because it measures up to these standards so splendidly that the Iowa Academy of Science ranks so high among similar organizations the nation over. The meeting last year was one of the best attended and had the fullest program of any of the Academy's gatherings. The fact that there is a call for recognition in the constitution of the sectional organization of the Academy shows that the continued growth in membership and in number of papers presented has made the meeting by sections a permanent part of the Academy's plans.

Affiliation with the American Association for the Advancement of Science has been perfected in accordance with the constitution and bylaws of that body. In accordance with those provisions our Academy is entitled to a representative on the Council of the Association. The President of the Academy appointed the Secretary as that representative for the recent meeting at Chicago and it will be well that some one shall represent us at the coming meeting at Toronto. This affiliation is a benefit to the Academy financially and it should be helpful also in a scientific way, uniting us with the great forces of progress throughout the country at large.

It is a matter of sincere regret to the Secretary that it has been impossible to make any progress with the publication of the Proceedings of the Iowa City meeting. The law which abolished the offices of state printer and binder and provided for printing by contract stated that no contracts could be let at prices in excess of those specified under the old system. When costs of material and labor mounted so high printers could not or would not submit bids within the legal limits. Hence it has been impossible for a year to have any reports published. The recent legislature has enacted a new law creating a printing board and it is hoped that this board will soon be able to carry on the State's printing business in a more normal way and issue its reports in a reasonable length of time.

The plan which was adopted last year, of an editorial committee to assist the Secretary in editing the manuscripts submitted, has proved very acceptable. The members of the committee have been most kind in reading the papers assigned them, and have as well made most trenchant, though kindly and helpful criticisms. May I quote briefly from one of these? The writer says: "All men sin more or less when it comes to putting their work in writing. Some sin a great deal more than others. The two outstanding sins are long loose disconnected sentence structure and the superfluous use of punctuation marks. Both faults could be corrected easily if men would take more care and thought and more time in preparing their papers for publication." The fitness of these statements is beyond dispute.

I wish, however, to make one suggestion regarding the appointment of the editorial committee, and that is that it be by the Secretary, in an informal way. I am convinced that it will be to the best interests of all concerned that as few persons as possible know the personnel of the committee. This will reduce to a minimum the possibility of ill-will because of any criticisms which may be made of papers submitted. I hope this suggestion will meet with your approval.

In accordance with a minute of the last meeting there is to be offered for your consideration a revised constitution. This includes practically all the amendments which have been adopted since 1903 and also certain other changes and additions which the work of the Academy has shown to be desirable. The noteworthy points are: the discontinuance of the Council of the Academy, which has been an accomplished fact for some years; the disuse of the classes of Corresponding Fellows and Corresponding Associates; and the changing of the membership of the Executive Committee, providing for one vice president instead of two and the substitution of the presidents of the sections for the elective members. A number of bylaws have been appended, to provide for the time of meetings, quorum for business, representation on the Council of the American Association for the Advancement of Science, an editorial committee and the organization of sections of the Academy. This constitution has been carefully considered by the Executive Committee and it is believed that it embodies those provisions which will best fit the present needs of the Academy.

Let me congratulate the Academy upon its solid growth and its lively perennial enthusiasm. These characteristics are bearing fruit in the elevation of the plane of scientific endeavor and achievement in the state and are certain to react in the continued advance and development of our society.

Respectfully Submitted,
James H. Lees,
Secretary.

TREASURER'S REPORT

RECEIPTS

Cash on hand, April 24, 1920	$182.81
Transfer and entrance fees	87.00
Annual dues from members	384.60
Eighty-nine A. A. A. S. dues of $4.00 each	356.00
Entrance fee, one new member A. A. A. S.	5.00
Deposit by parties desiring A. A. A. S. membership lists	4.50
Refund overpaid by A. A. A. S.	7.00
Sale of Proceedings	6.02
Unaccounted for	1.00
Total	$996.93

DISBURSEMENTS

Postage and supplies for Secretary	$ 6.25
Clerical help and postage for Treasurer	13.80
Telegraph and telephone service	2.69
Printed programs, 1920 meeting	13.00
Honorarium to Secretary	75.00
Honorarium to Treasurer	25.00
To Miss Newman, distributing Vol. XXVI	10.00
Refund to members	5.50
Remittance of 89 A.A.A.S. dues of $4.00 each	356.00
Remittance of one entrance fee, A. A. A. S.	5.00
Remittance for membership lists	4.00
Overpaid refund returned to A. A. A. S.	7.00
Deposit in savings account	400.00
Cash on hand, April 29, 1921	73.69
Total	$996.93

The total assets of the Academy are as follows:

Cash on hand as stated above	$ 73.69
Savings account	400.00
Accrued interest to May 1	4.75
Total	$478.44

In addition to this there are outstanding dues amounting to twenty-five or thirty dollars the greater part of which will eventually be paid. The total assets may then be estimated as close to five hundred dollars. This amount is the largest balance ever reported at any annual meeting of the Academy. This condition is partly due to the increased membership and general prosperity of our organization but it is also partly due to the fact that nearly ninety additional members have already paid in their 1921 dues. There are no liabilities other than those of the current meeting.

The treasurer wishes to call attention to the fact that nearly twenty-five per cent of the new members elected at the Iowa City meeting one year ago have failed to respond to the notices of their election and pay their entrance fees. Since this percentage is much too high and far greater than usual the treasurer wishes to suggest two probable causes, first, too often persons nominated have not been consulted as to their wishes and they are uninformed about the Academy and its purposes, second, the names and addresses of the candidates are in some cases incompletely and inaccurately given with the results that the notices are missent or returned unclaimed. A few words of explanation and a moment's care to verify the name and address should reduce this shrinkage to a minimum.

Respectfully Submitted,

A. O. Thomas,
Treasurer.

Report Declared Correct.
Doty
Stanley
Auditing Committee.

COMMITTEE ON SECRETARY'S REPORT

The committee on Secretary's report wishes first of all to commend the kind and efficient services of the Secretary. To him more than to any other one person is due the growth and prosperity and general good will which distinguish our Academy.

The Committee recommends that the Nominating Committee be instructed to name a delegate to represent the Iowa Academy of Science at the next meeting of the American Association for the Advancement of Science. It is suggested that the person selected should be one who is an habitual attender of the Association's meetings.

The Committee commends the work of the editorial board. For the protection of our members and of the Academy itself, the material published in the Proceedings should be carefully edited. We concur in the Secretary's recommendation that this board should be selected by himself without publicity. If this method requires action by the Academy, such action should be taken.

Respectfully submitted,
HENRY S. CONARD, *Chairman,*
F. M. BALDWIN
R. B. WYLIE

The report of the committee was adopted.

REPORT OF THE COMMITTEE TO INVESTIGATE THE DRAINAGE OF AMANA LAKE.

To the Iowa Academy of Science:

Your special committee, appointed to investigate the report of the contemplated drainage of the lake at Amana, widely known for its bed of American Lotus, or *Nelumbo lutea* (Wild.) Pers. presents the following report:

Information was received from prominent members of the Amana Community, in the summer of 1920, that the immediate drainage of the lake was not contemplated, and nothing further was done until recently, when additional information was received from W. F. Moerschel, Secretary of the Amana Community, and other prominent members, and a brief statement of the situation is here presented:

Complaint is made that for five or six weeks each summer, during the flowering season of the Lotus, great numbers of visitors come to this lake, and that all too frequently these visitors do not respect the rights of the Community, but cut wires, trample upon cultivated ground, and otherwise trespass upon the property of the Community.

Furthermore it is declared that the Sunday crowds are especially large and troublesome, and that their presence disturbs the peace and quiet of the Sabbath day, and has a demoralizing effect on their young people. The privilege of erecting refreshment booths near the lake was denied by the Community, but use was made of the nearby highway for that purpose by outsiders, and this added to the annoyance caused by the crowds.

The Amana people say that they do not wish to be harsh, that they have no objections to visitors during six days of the week if they avoid serious trespass, and that they will gladly preserve the lake if the evils herein mentioned are corrected.

In view of all the circumstances your Committee presents the following recommendations:

1. That the Iowa State Board of Conservation be requested to enter into negotiations with the Amana Community for the purpose of securing the power to enforce such rules and regulations as may be necessary or desirable for the perpetuation of the lake and its Lotus-bed.

2. That, in view of the scientific interest and value of the remnants of natural tracts which still linger in our state, a committee of three be appointed, which shall prepare for the press of the state such articles as will assist in creating and developing a public sentiment which would not only prevent trespass in the State parks, but would protect and encourage all citizens who are trying to preserve some of the natural beauty of the state on privately owned tracts.

3. That all organizations interested in the conservation of natural conditions in the state be invited to participate in this effort, and that the committee to be appointed be authorized to work jointly with representatives of such organizations.

Respectfully submitted,
B. Shimek
Henry S. Conard
George Bennett.

REPORT OF COMMITTEE ON REFORESTATION

Whereas,

The need of reforestation, especially on the rougher lands along the streams of Iowa, is being more and more appreciated by the thoughtful people of our state, and calls for encouragement by legislative action;

Whereas,

Reforestation is recognized as one of the most important problems of conservation, and demands immediate attention particularly because of the need of restoring portions of our state parks;

Therefore, be it resolved,

That the Iowa Academy of Science respectfully recommends to the General Assembly of Iowa the enactment of suitable laws and regulations for the encouragement of reforestation in the state, and that the direction of all work in reforestation in our state be placed in the hands of the Iowa State Board of Conservation, where it logically belongs.

That a copy of these resolutions be transmitted to the next General Assembly, and to the Governor of Iowa.

Respectfully submitted,
S. Shimek
George Bennett
Henry S. Conard
Committee.

REPORT OF COMMITTEE ON RESOLUTIONS

We desire to pay a tribute of loyal recognition and deep affection to the memory of Mrs. S. J. Kirkwood of Iowa City, whose spirit passed into the eternal in the early hours of Thursday, April 28, 1921. The record of the Governor of our State during the Civil War is indelibly written in the annals of Iowa, and the going from our midst of this remarkable woman, who after sharing his burdens and responsibilities, lived so long in the commonwealth they both served so well, rounding out almost a century of years, is an occasion, we feel, for loyal and extended recognition.

We repeat, we desire to pay tribute to the memory of Mrs. Kirkwood, also requesting that the Secretary convey these sentiments to the family and friends of the deceased.

Be it resolved, that the Iowa Academy of Science send greetings to Madame Curie, on this the occasion of her first visit to the United States and that we express our highest appreciation of her monumental work in the field of radio activity.

The selection of our state for holding the first National Conference on the very important subject of park areas, from a national, state, county and municipal standpoint, their setting aside and administration, which took place in Des Moines in January last, we believe to be of signal value in the evolution of everything pertaining to the advance of natural science and the country's general welfare, and we congratulate the State Government of Iowa and the Iowa State Board of Conservation on what has been accomplished, also expressing the hope, that what has been so far effected, will be materially increased in the immediate succeeding years.

We learn that the national organization of Camp Fire Girls is behind a movement to have March 1st., the first day of spring, set aside as National Bird Day. We heartily endorse their movement and wish them every success in carrying such to completion.

It is with lively satisfaction we present our compliments to President Hillman and the faculty and student body of Simpson

College, who have so well and wisely provided for our convenience and comfort during our stay in the college city; and to the members of the progressive Commercial Club, who in such pleasant fashion, enabled us to see so much of the city's fine environment. Will they all kindly receive our cordial thanks for this most agreeable expression of co-operation and welcome from Indianola, the home of friendly greeting and hearty goodwill.

George Bennett
M. E. Graber.

REPORT OF THE MEMBERSHIP COMMITTEE

For transfer from Associate to Fellow.—Bennett, Geo., Coss, Jas. A., Dewey, A. H., Fenton, Fred A., French, R. A., Hadley, S. W., Harrison, Bruce M., Howell, Jesse V., Paige, F. M., Patterson, T. L.—10.

For Election as Fellows.—Dr. Edward Bartow, Head of Chemistry Dept., S. U. I., Iowa City. Dr. J. C. Gilman, Botany Dept., I. S. C., Ames, Iowa. Dr. (Mrs.) Eula D. McEwan, Geology Dept., Simpson College, Indianola, Iowa. Dr. L. Chas. Raiford, Chemistry Dept., S. U. I., Iowa City, Iowa. Prof. Fred C. Werkinthin, Botany Dept., I. S. C., Ames, Iowa.—5.

For Election as Associates.—Anderson, Henry, Mt. Vernon; Averill, W. A., Mt. Vernon; Benedict, A. A., State College, Ames; Bisgard, Vernie, Harlan; Brothers, Prof. Chester R., Mt. Pleasant; Browning, Glenn H., Mt. Vernon; Butler, L. W., I. S. C., Ames; Cleveland, Joseph, Mt. Vernon; Coffin, Prof. T. M., Coe College, Cedar Rapids; Craver, C. Wilbur, Mt. Pleasant; Davis, Geo. E., 117-10th St., Ames; Dietz, F. M., Ames; DuBridge, Lee A., Mt. Vernon; Ellsworth Winifred, Grinnell; Everman, Irene, Centerville; Fitzpatrick, F. L., Iowa City; Gilmore, Katherine, Mt. Pleasant; Goshorn, Arthur, Winteset; Goshorn, Mrs. Arthur, Winterset; Gouwens, Cornelius, Ames; Higgins, Lafayette, Sr., 1144-25th St. Des Moines; Hitchings, Mitford, Independence; Holmes, J. S., Ames; Kiefer, Earl C., Ames; King, G. E., Mt. Pleasant; Krull, Wendell, Tripoli; Laird, Donald A., Iowa City; Lewis, Sarah, Iowa City; Mason, O'Neal, Mt. Vernon; Miller, Cephas C., Mt. Vernon; Milas, Nicholas, Cedar Rapids; Mortensen, Prof. F. C., Cedar Rapids; Nelson, Frances J., Dayton; Norwood, Chalmers, Mt. Pleasant; Pace, Prof. E. R., Indianola; Parline, W. A., Indianola; Peterson, Ben, Cedar Rapids; Porter, R. H., Ames; Raeder, J. M., Ames; Radspinner, W. A., Ames;

Reed, Ervin E., Monticello; Rouse, Glenn F., Mt. Vernon; Rusk, Prof. W. J., Grinnell; Shafer, Sherman, Mt. Vernon; Smith, Kenneth, O., Mt. Vernon; Venell, Reuben F., Centerville; Weeks, Rev. Leroy Titus, Emmetsburg; Wentworth, Chester, K., Iowa City; Willson, L. H., Ames; Young, Paul A., Cedar Rapids.—49.

LIST OF MEMBERS IN ATTENDANCE

J. Allen Baker, Indianola; B. T. Baldwin, Iowa City; F. M. Baldwin, Ames; George Bennett, Iowa City; P. A. Bond, Iowa City; E. H. Collins, Iowa City; Miss Julia P. Colpitts, Ames; H. S. Conard, Grinnell; George E. Davis, Ames; Miss Winifred Ellsworth, Grinnell; C. W. Emmons, Indianola; C. Bert Gose, Indianola; M. E. Graber, Sioux City; J. E. Guthrie, Ames; B. M. Harrison, Ames; Albert Hartzell, Ames; Paul S. Helmick, Iowa City; Wm. A. Hemmings, Mount Pleasant; H. E. Jaques, Mount Pleasant; Harry M. Kelly, Mount Vernon; G. E. King, Ames; Nicholas Knight, Mount Vernon; Wm. Kunerth, Ames; C. E. Lane, Iowa City; James H. Lees, Des Moines; O. E. Lowman, Fayette; Harold L. Maxwell, Ames; Mrs. Eula D. McEwan, Indianola; F. M. McGraw, Mount Vernon; D. W. Morehouse, Des Moines; C. C. Norwood, Mount Pleasant; L. H. Pammel, Ames; T. L. Patterson, Iowa City; L. Chas. Raiford, Iowa City; John F. Reilly, Iowa City; H. L. Rietz, Iowa City; Miss Maria M. Roberts, Ames; L. S. Ross, Des Moines; W. J. Rusk, Grinnell; W. E. Sanders, Des Moines; B. Shimek, Iowa City; L. P. Sieg, Iowa City; B. F. Simonson, Fayette; O. H. Smith, Mount Vernon; F. C. Stanley, Oskaloosa; Miss Lorle I. Stecher, Iowa City; G. W. Stewart, Iowa City; Dayton Stoner, Iowa City; F. A. Stromsten, Iowa City; V. A. Suydam, Grinnell; A. O. Thomas, Iowa City; George E. Thompson, Ames; A. C. Trowbridge, Iowa City; F. M. Weida, Iowa City; C. W. Wester, Cedar Falls; S. J. A. Wifvat, Des Moines; Lawrence H. Willson, Ames; B. H. Wilson, Mount Pleasant; Guy West Wilson, Fayette; R. B. Wylie, Iowa City.

REVISED CONSTITUTION OF THE IOWA ACADEMY OF SCIENCE, 1921.

Sec. 1. *Name.*—This organization shall be known as the Iowa Academy of Science.

Sec. 2. *Object.*—The object of the Academy of Science shall be the encouragement of scientific work in the state of Iowa.

Sec. 3. *Membership.*—The membership of the Academy shall consist of, (1) honorary fellows, (2) life fellows, (3) fellows, and (4) associates. Honorary fellows shall be elected from especially productive scholars in science. Fellows shall be elected from those persons who are actively engaged in scientific work. Any person who is interested in the progress of science even though not directly contributing to original research, may be elected an associate.

An honorary fellow must be nominated by ten fellows of the Academy. This nomination, together with a record of the achievements in science of the nominee must be given the secretary and by him to each fellow previous to the annual meeting at which the election is to occur. A unanimous vote of the fellows present is necessary for the election of an honorary fellow. Proposals for membership as fellows or associates shall be made by two members of the Academy in good standing and shall then be approved by the membership committee. All elections to membership shall be made at the annual meeting, except as hereafter provided. The assent of three-fourths of the members present is required for the election of fellows or associates.

Fellows, including life fellows, shall be eligible to hold all offices of the Academy and to vote on all questions which may arise for decision.

Associates shall be entitled to all the privileges granted fellows except those of holding the four elective offices provided for in Section 5, and of voting on those matters specifically limited to fellows.

Sec. 4. *Fees.*—There shall be required of each fellow an entrance fee of $3.00, also an annual fee of $1.00, due at each annual meeting following the one at which time he was elected. A fellow may become a life fellow on the payment of $15.00 which shall be additional to the entrance fee. This life membership fee is to be invested and only the interest on the same may be used for current expenses of the Academy.

An annual fee of $1.00 shall be required of each Associate.

Fellows and associates in arrears for two years and failing to respond to notification from the treasurer shall be dropped from the Academy roll.

Fellows and associates who desire to avail themselves of joint membership in the Academy and the American Association for the Advancement of Science shall pay to the treasurer of the Academy $5.00 annually, $4.00 of which sum shall be transmitted by the treasurer to the American Association for the Advancement of Science. For life fellows of the Academy the joint fee shall be $4.00 annually.

The fiscal year of the Academy shall end September thirtieth.

Sec. 5. *Officers.*—The officers of the Academy shall be a president, a vice-president, a secretary and a treasurer. These officers shall be elected at the annual meeting from the fellows in good standing. Their duties shall be such as ordinarily devolve upon these officers. They together with the presidents of the sections of the Academy shall constitute the executive committee.

The executive committee shall have the authority to fix the time and place of meetings and to transact such other business as may need attention between the meetings of the Academy. It may elect to associate membership such persons as may be nominated in the interval between annual meetings.

Sec. 6. *Papers.*—All papers presented to the Academy and offered for publication in its Proceedings shall be the result of original investigation. The executive committee may arrange for public lectures or addresses on scientific subjects.

Papers from non-members will be accepted for presentation before the Academy and for publication in its Proceedings only upon vote of the executive committee.

Sec. 7. *Proceedings.*—The secretary shall each year publish the Proceedings of the Academy in the form prescribed by law. These Proceedings shall include the minutes of all meetings held during the year together with such other matter as is deemed of importance, and such of the papers presented to the Academy as are offered and accepted for publication.

Sec. 8. *Amendments.*—This constitution may be amended or revised at any annual meeting by assent of a majority of the fellows present, provided that notice of proposed amendment or revision has been given to the fellows at least one month previous to the meeting and that absent fellows may deposit their votes, sealed, with the secretary.

Bylaws

Art. 1. *Meetings.*—Unless otherwise decided by the executive committee the annual meetings of the Academy shall be held on or about the last Friday and Saturday of April.

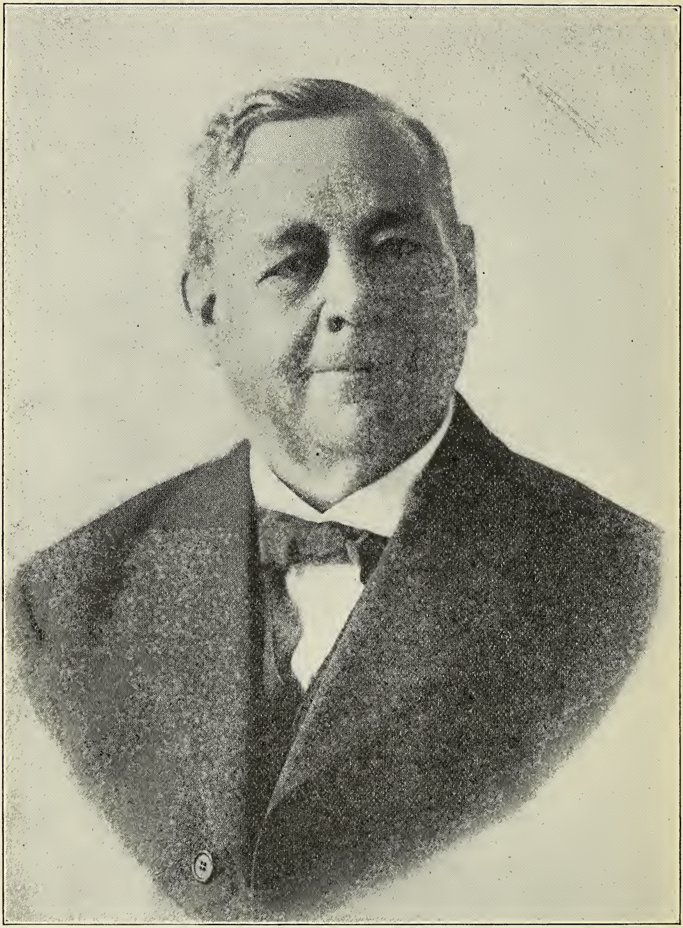
Art. 2. *Quorum.*—A quorum shall consist of fifteen members, of whom at least ten shall be fellows.

Art. 3. *Representative in A. A. A. S.*—This Academy having affiliated with the American Association for the Advancement of Science and being entitled to a representative on the Council of that Association, such representative shall be elected from the fellows by the Academy at the time of election of officers. In case the person so elected is unable to attend the meeting of the Association for which he was chosen the president of the Academy is authorized to choose another person in his place.

Art. 4. *Editorial Committee.*—The secretary may request members of the Academy to edit for him papers which are presented for publication. Such members with the advice of the secretary, shall have the right to correct, revise or reject any papers given them to edit. Appeal from their decision may be taken to the executive committee whose decision shall be final.

Art. 5. *Sections.*—Sections of the Academy shall be organized as follows: botany, geology, zoology, physics, chemistry, mathematics, together with their allied subjects. Other sections may be organized as the need may arise. These sections shall hold such meetings as their officers shall decide. Each section shall elect annually a president and a secretary, who shall hold office until their successors are elected. The presidents of the sections even though these sections may be organized as sections of their national societies shall be ex-officio members of the executive committee of the Academy.

Art. 6. *Revision.*—These bylaws may be added to or modified at any annual meeting by a majority of the members present.



DR. E. W. STANTON

IN MEMORIAM

E. W. STANTON

Doctor Stanton was born at Waymart, Pennsylvania, October 3, 1850, and died at Canadaigua, New York, September 12, 1920. He graduated at Iowa Agricultural College in 1872, a member of the first class, and was given the degree of L. L. D. by Coe College in 1904. He was connected with Iowa State College in various capacities; as instructor and professor of mathematics and political economy, dean, vice-president and acting president, secretary of the Board of Trustees, financier, philanthropist, administrator and educator. This in brief epitomizes the career of Doctor Stanton. His success in the world was due to his individual effort. I take it Doctor Stanton had, in part at least, to make his own way through college. He did work of various kinds for Professor Jones who during the college days of Doctor Stanton had charge of mathematics.

It was because of his untiring fidelity to his superiors and his zeal to do his work well that he came to occupy the position he did in the college and the community and state. His work is finished but Doctor Stanton's name is a sweet memory to those who came under his influence in the class room or college community. There was always a cheerful and buoyant spirit in the class room. It was in the nature of a splendid service to all. With him it was always "Can I help you to understand the problem that is before you?" A hint here or a hint there made the student see the problem in its true light. There are teachers of many kinds. Doctor Stanton was of the exceptional kind. Indeed, it is a rare gift to be able to take an obscure problem and present it in such a way that the road to its solution and perfect understanding is clear. Too, in his case, we may say that teachers are born, not made. Doctor Stanton insisted on good work and the student generally responded to his appeal. How could he do otherwise? It was always a kindly admonition to do better work.

Most students today do not come into intimate contact with their instructors. This is possible only when classes are small, but today the class room is practically the only contact. There were many occasions in recent years as Junior Dean, where Doctor Stanton had occasion to know the inner feelings of many students who came to see him and talk over their many difficulties. I am sure the good wholesome advice given has made many a student feel his own responsibility as a student and for the good of all. Doctor Stanton had many warm friends in the college community and the state. Many a time I have gone to him to talk over some difficulties and with an open heart and mind he expressed himself freely and feelingly on the subject in hand. He was always sincere and when he gave his word yes or no, it meant that he would abide by his decisions. Doctor Stanton was loyal to his friends. No one could say he ever betrayed them and this is the test of real friendship.

Doctor Stanton was naturally conservative, not only in a business way, but in educational matters as well. The old method looked good to him until new ideas had proven their worth.

The recent war weighed on him in many ways; the responsibility of looking after the welfare of the student body, especially during the influenza epidemic, made inroads on his physical strength. I wonder how many realized this responsibility? Anxious parents, not knowing conditions sometimes, were critical and a sensitive man like Doctor Stanton took to heart some of these ill timed remarks which undermined his health and I think it was never quite the same later. Whatever may be said, he did the work before him in a conscientious way, with the feeling that he did his best.

In the passing of Doctor Stanton, Iowa State College has lost a true friend and a many sided man, who has left his impress for a good wholesome life. He has left his impression on the many whose privilege it was to hear his kindly voice and feel his kindly handshake. His educational work is his monument, and grateful coworkers, students and friends will cherish his memory as long as industrial education is a part of this commonwealth.

L. H. Pammel.

Papers Presented at the Thirty-fifth Annual Meeting

THE ADDRESS OF THE PRESIDENT

AMERICAN SCIENCE

NICHOLAS KNIGHT

A year has gone since as an organization we met at Iowa City, and now we find ourselves face to face with the program and responsibilities as well as the festivities of our thirty-fifth annual meeting. As always it has been a year of losses of scientific men from the state, but we have gained others, and as we survey the field, it has proved a year of progress and achievement. The Iowa Academy of Science retains its prestige among sister organizations, and possibly has added to the laurels it already had won.

This is a wonderful period in human history—this time of reconstruction in which we find ourselves living and doing the work of our hands and brains. A writer in one of the popular magazines has declared that when the sun set on the thirty-first of July, 1914, it went down on the world as men knew it up to that time, and when it rose on the first day of August, 1914, it rose on an entirely new world, with new problems and new duties and new responsibilities. That was a remarkable period, the four years, three months and ten and a half days of the titanic conflict. Great progress was made not only in the means and instruments of destroying human life, but also in the arts and sciences and in the methods of conserving and prolonging human existence.

The period of the war had to come to an end. Who of us here assembled can ever forget that memorable morning in November when we were aroused from our slumbers by the ringing of the joy bells and the blowing of the whistles, and we exclaimed as we congratulated each other in the home or met upon the street "the armistice has been signed; the years, months and days of the cruelest, bloodiest and most needless war in the history of the human race have come to an end"?

But that sentiment was only a partial truth. The joy bells did mark the end of the great conflict, but they likewise ushered in the new era, the time of re-construction, more important and wonderful, fraught with more serious problems, and with greater difficulties and responsibilities, yea with greater privileges, than even the time of the great war itself. It is in this age that we must live and move and have our being.

The world at large and more particularly Europe, is staggering from the effect of the cruel blows it received in the World War, and we have come to realize that recovery can not be rapid, but will require a generation or two, and possibly even a longer time.

Where will the world's bright young men and women, fired with a lofty ambition to succeed in life, seek an education in the next decades? Egypt, Greece, Rome, France, the Florentine Republic, England, and lastly Germany, have each had their day as the center or metropolis of the world's intellectual life. And quite likely Germany surpassed them all in pushing forward the frontiers in almost every field of knowledge. Reliable statistics have shown that for some decades prior to the fated August 1, 1914, fifty-five per cent of all the advanced or productive scholarship was confined within the borders of the German Empire; while all the rest of the world—the United States, England, Belgium, France, Japan, Italy and all the others had to be content with the remaining forty-five per cent.

But Germany is bleeding and prostrate from the long and terrible war. Many of her brightest and most promising scientific men and productive scholars made the supreme sacrifice on the field of battle. Her finances are in ruins. We had occasion to send a dollar and a half to Heidelberg last week. Ordinarily six marks would have been purchased but now it requires ninety-one marks to equal the American money. Belgium has made rapid progress in reconstruction, but yesterday as we paid a bill in Antwerp, only seven and a half American cents could purchase a Belgian franc. Germany in common with the other nations ruined by the war must engage in a fierce struggle for existence to ward off under-nourishment and starvation, and history shows that under such circumstances, there is small opportunity to consider the productive scholarship that adds to the world's knowledge. For possible decades in the future the children will continue under-nourished and many will be deprived of even the rudiments of an education.

The countless millions of dollars worth of high explosives that were used in the war can be produced only by the free use of nitric and sulphuric acids. Of course we all understand that nitric acid in the form of nitrates is an important fertilizing material, of which vegetation has been deprived; and sulphuric acid is required to render phosphate rock soluble and available for the growing plants. The soil, accordingly, is also suffering from starvation and will not produce the usual crops. Here is an opportunity for the co-operation of scientists in restoring the land to normal conditions.

Among the civilized nations we are almost the only one to escape with our material resources unimpaired. Indeed, in some lines, we have almost the only raw materials that escaped destruction in the war. Shall the American people rise to the occasion and realize our great responsibility and our matchless opportunity in the matter of advanced learning and productive scholarship?

Material wealth is an important factor, but it is only one element that makes possible productive scholarship on a vast scale. Will American public sentiment sustain the scholar, as in a measure he must withdraw from the public view, and spend his best years in his library or laboratory? Long years of training are imperative to develop the scholar who can achieve enduring results.

In Germany before the war, the man who had earned the doctor of philosophy degree had hardly made a beginning. With a meager compensation he must serve the department head long years as assistant. When promoted to the rank of PRIVAT DOCENT his salary, if possible, was still smaller. But he had ample opportunity to study and investigate under the stimulating influence of the great teacher. If he was successful, in the course of the years, he would attain the rank of extraordinary professor, and after a time, and no longer young, he might attain the goal of his ambition, and himself become the head of the department with the proud title of professor.

German society and the Imperial German government would applaud the man who would choose such a career. He would be patted on the back and those high in authority would say to him, "well done good and faithful servant." Society would erect to his memory a monument of as fine and pure a marble, and it would pierce the blue as high as any ever erected to distinguished statesmen, generals or admirals.

We would grow impatient under the prolonged period of training and would demand more immediate results. And yet since the war, there has been a change in the public sentiment in the United States. There has been a keener appreciation of science and the people are more alive to its wonderful possibilities. More of our citizenship realize as never before the value of training and education, especially the kind that educates. The people are in a plastic, receptive mood, as they understand that the war was won not so much by brute force, as was the case in former wars, but was won by brains, one set of nations striving to outdo and surpass the others by the sheer force of intellect.

In these reconstruction days the Iowa Academy of Science has an important mission to perform. We delight to think of it as an organization making its contribution to knowledge, encouraging its members to build up the waste places in Iowa science, and doing our part in every possible relation.

We have come together in this our thirty-fifth annual gathering, bringing with us some of the precious sheaves of truth we have garnered during the year. The meeting may not be as large as the one last year at Iowa City but it should be one of inspiration to all, and as we separate let us face the future with renewed courage, with a stronger determination to continue even more actively in our various fields of endeavor. Our number of specially trained should increase, and the work we do should be sufficient in quantity and of that high quality that will give us a good standing among other learned societies. We have our own part in making our nation a world power in the field of productive scholarship.

A CHEMICAL STUDY OF DOLOMITES.

NICHOLAS KNIGHT

Deodat Dolomieu was born in Dolomieu, France, June 23, 1750, and died November 16, 1801. In infancy he was created a Knight of Malta and seemed precocious in many directions. When nineteen years of age he quarreled with a companion and killed him. He was condemned to die for his crime, but after nine months' imprisonment, he was pardoned on account of his youth. He early became interested in geology and mineralogy, and wrote some important treatises on his favorite subjects, especially while residing in Metz, the interesting old capital of Lorraine.

He discovered dolomite while making an extended tour and observations among the Alps in 1789-90. The mineral was first described by him in 1791, and the name was bestowed upon it in honor of the discoverer.

The dolomite mineral and rock are important and interesting from both a theoretical and practical standpoint. Much work has been done upon them, and the mineral can be artificially produced by a number of different methods.

Marignac was probably the first to make it synthetically. His method was to heat calcium carbonate and a solution of magnesium chloride to 200° under a pressure of fifteen atmospheres. In a closed gun barrel J. Dorocher heated porous limestone and dry magnesium chloride to about 1200°. The vapor of the chloride permeated the porous limestone, which was partly transformed into dolomite. In a similar way, it has been suggested, the heat in the neighborhood of volcanoes may produce the mineral and rock.

One of the simplest methods was devised by C. Sainte-Claire Deville. He saturated chalk with a solution of magnesium chloride and heated the mixture upon a sand-bath. More or less of the materials changed into dolomite.

By heating powdered calcite with magnesium sulphate to 200° in a closed tube von Morlot obtained a mixture of dolomite and calcium sulphate. It has been suggested by Haidinger that this reaction accounts for the frequent association of dolomite and gypsum.

T. Sterry Hunt conducted a long series of experiments on the precipitation of calcium and magnesium carbonates, from which he reached the conclusion that dolomite is simply a chemical precipitate. This view has not been generally adopted.

In more recent times, 1909, G. Linck published a report of a new method of making dolomite. He mixed solutions of magnesium chloride, magnesium sulphate, and ammonium sesquicarbonate, and then added a solution of calcium chloride. An amorphous precipitate came down, which on gentle heating for some time in a closed tube became crystalline. This had the composition and optical properties of dolomite. Linck believes that his experiment explains the formation of marine dolomite, and that the ammonium salt necessary can easily result from the decomposition of organic substances.

The ideal dolomite, $CaCO_3 \cdot MgCO_3$, would contain:

	PER CENT
$CaCO_3$	54.35
$MgCO_3$	45.65

But such a dolomite is ideal and does not exist in nature.

The Niagaran dolomite, the formation in northeast Iowa, which has, indeed, a wide distribution, being found in many states, is an approach to the ideal. The composition of different layers varies, but a fairly typical specimen would or might reveal:

	PER CENT
$CaCO_3$	54.35
$MgCO_3$	43.65
SiO_2	1.00
Al_2O_3 and Fe_2O_3	1.00
	100.00

We have examined dolomites, so-called, from many different countries and find some that are properly termed dolomites, while others are magnesian limestones, with only a small percentage of magnesium. Some contain very little of either calcium or magnesium, but are quite pure sandstones.

1. Specimen from New Almadin, California.—This is a hard, greyish-white variety. It consists of large compact crystals, with one surface coated with a brown deposit. The specific gravity is 2.8

	PER CENT
SiO_2	0.40
Fe_2O_3	8.57
Al_2O_3	0.00
$CaCO_3$	53.58
$MgCO_3$	37.86
	100.11

2. Hell Fire Rock, Wahsatch Mountains, Utah.—The analysis revealed that it is quite a pure sandstone, and can not be classed with the dolomites. The rock is white, crumbly, and fine granular in appearance. The specific gravity is 2.2.

	PER CENT
SiO_2	95.29
Fe_2O_3	2.88
Al_2O_3	1.68
$CaCO_3$	0.16
$MgCO_3$	0.00
	100.01

3. Specimen from Hurley, Wisconsin.—The sample contained a number of quartz crystals, also iron pyrite and siderite. The exterior bore a number of dolomite crystals of a pinkish hue, and only the dolomite crystals were taken for the analysis. The specimen proved a fairly typical dolomite. We did not determine the specific gravity.

	PER CENT
SiO_2	2.56
Fe_2O_3	0.27
Al_2O_3	0.00
$CaCO_3$	48.52
$MgCO_3$	40.02
	100.37

4. Specimen from Brosso, Piedmont, Italy.—This sample has a peculiar appearance, and consists of large olive-green crystalline lumps, resembling clay balls. They are very compact and are held together by ferric oxide. The specific gravity is 2.91. From the analysis the specimen may be fairly classed as a dolomite.

	PER CENT
SiO_2	4.97
Fe_2O_3	6.44
Al_2O_3	0.00
$CaCO_3$	50.46
$MgCO_3$	37.82
	99.69

5. Specimen from Georgetown, New Mexico.—Dull white rhombohedral crystals. The analysis shows the mineral is quite a pure calcite rather than a dolomite. The specific gravity is 2.46.

	PER CENT
SiO_2	0.57
Fe_2O_3	0.00
Al_2O_3	0.55
$CaCO_3$	98.32
$MgCO_3$	0.88
	100.38

6. Specimen from Lancaster County, Pennsylvania.—The pure white rhombohedral crystals are a fairly typical dolomite. The specific gravity is 2.31.

	PER CENT
SiO_2	0.48
Fe_2O_3	1.58
Al_2O_3	1.63
$CaCO_3$	56.60
$MgCO_3$	40.50
	100.79

7. Specimen from Diembachkogel, Styria, Austria.—It is a typical dolomite, with large white rhombohedral crystals, having a specific gravity of 2.89.

	PER CENT
SiO_2	0.40
Fe_2O_3	1.52
Al_2O_3	0.00
$CaCO_3$	54.39
$MgCO_3$	43.51
	99.81

8. A dolomitic limestone from Kasota, Minnesota.—The specimen is massive, gray, soft and porous, with a reddish coloration on the surface. The specific gravity is 2.61.

	PER CENT
SiO_2	9.41
Al_2O_3	1.74
Fe_2O_3	0.96
$CaCO_3$	53.67
$MgCO_3$	34.82
	100.60

9. Specimen from St. Louis, Missouri.—The rhombohedral crystals are on the surface of a light gray compact, massive rock; they contain an admixture of silica. The specific gravity is 2.52.

	PER CENT
SiO_2	25.70
Fe_2O_3	0.00
Al_2O_3	24.65
$CaCO_3$	47.34
$MgCO_3$	2.98
	100.67

10. Specimen from Orange County, New York.—Pink and white rhombohedral crystals with a specific gravity of 2.74.

	PER CENT
SiO_2	2.59
Fe_2O_3	0.57

Al_2O_3	0.00
$CaCO_3$	56.80
$MgCO_3$	39.39
	99.35

11. Specimen from Fassathal, Tyrol.—A dark gray central mass covered with a layer of dark rhombohedral crystals. A mixture of both portions was taken for the analysis. The specific gravity is 2.82.

	PER CENT
SiO_2	00.79
Fe_2O_3	00.23
Al_2O_3	0.71
$CaCO_3$	60.32
$MgCO_3$	38.78
	100.83

12. Specimen from Columbia, Pennsylvania.—This sample is a black rock containing rhombohedral and irregular shaped crystals, soft and with a bright lustre. The analysis shows it to be a limestone rather than a dolomite. The specific gravity is 2.69.

	PER CENT
SiO_2	0.80
Fe_2O_3	0.31
Al_2O_3	0.20
$CaCO_3$	95.08
$MgCO_3$	3.53
	99.92

13. Specimen from Lockport, New York.—The rocks belong to the Niagaran formation, and are similar to those found in northeastern Iowa. The specimen consisted of pink and white rhombohedral crystals of a pearly lustre, over a dark gray compact interior. The specific gravity is 2.84.

	PER CENT
SiO_2	0.01
Fe_2O_3	2.07
Al_2O_3	2.39
$CaCO_3$	55.78
$MgCO_3$	39.35
	100.45

14. Specimen from Cumberland, England.—The crystals are both rhombohedral and irregular in form. There is a variety of color, including pink, white, black, brown and slate; also irregular masses of hard, compact, reddish crystals. The analysis was made from a mixture of the entire specimen. The specific gravity is 2.84.

	PER CENT
SiO_2	6.05
Fe_2O_3	8.04
Al_2O_3	3.40
$CaCO_3$	59.43
$MgCO_3$	22.85
	99.77

15. Specimen from Freiberg, Saxony.—The interior is finely granular and marble-like. The rhombohedral crystals on the exterior are brownish in color. The specific gravity is 2.87.

	PER CENT
SiO_2	0.55
Fe_2O_3	11.53
Al_2O_3	2.55
$CaCO_3$	54.37
$MgCO_3$	31.45
	100.45

16. Specimen from Lee, Massachusetts.—This rock is hard and white, resembling marble, with small shining rhombohedral crystals. The specific gravity is 2.87.

SiO_2	0.64
Al_2O_3 and Fe_2O_3	0.20
$CaCO_3$	65.30
$MgCO_3$	33.04
	99.98

17. Specimen from Eiserfeld, Westphalia, Germany.—It is composed of large white crystals, irregularly set together, and is accompanied by calcite and chalcopyrite. A few of the crystals are slate gray. The specific gravity is 2.80.

	PER CENT
SiO_2	0.64
Fe_2O_3	11.49
Al_2O_3	2.28
$CaCO_3$	61.89
$MgCO_3$	23.24
	100.41

18. Specimen from Niagara Falls, New York.—Irregular shaped crystals, which are pink, yellow, slate and black and are accompanied by calcite and selenite. The specific gravity is 2.8.

	PER CENT
SiO_2	1.01
Fe_2O_3	1.26

Al_2O_3	5.42
$CaCO_3$	66.41
$MgCO_3$	20.33
	100.43

19. Specimen from Cumberland, England.—The interior consists of a mass of white crystals, and the surface is composed of large red and irregular crystals. We mixed together both kinds for the analysis. Specific gravity 2.91.

	PER CENT
SiO_2	0.68
Fe_2O_3	11.09
Al_2O_3	2.85
$CaCO_3$	57.36
$MgCO_3$	28.42
	100.40

20. A dolomitic limestone from Rochester, New York.—A slate-colored rock with brown crystals on the surface. The specific gravity is 2.79. Both portions of the specimen were ground together for the analysis.

	PER CENT
SiO_2	3.05
Al_2O_3 and Fe_2O_3	0.31
$CaCO_3$	43.75
$MgCO_3$	52.96
	100.07

21. Specimen from near Gouverneur, New York.—The rock is a mixture of gray and white crystals and resembles ordinary marble.

	PER CENT
SiO_2	1.17
Al_2O_3	2.72
Fe_2O_3	0.17
$CaCO_3$	67.24
$MgCO_3$	29.88
	100.40

22. Specimen from Cape Breton Island.—This was kindly sent by the Honorable D. Ross MacDonald to whom we express our thanks.

	PER CENT
SiO_2	5.19
Fe_2O_3	0.41
Al_2O_3	2.54
$CaCO_3$	58.12
$MgCO_3$	38.40
	99.75

23. Specimen from Tuchshoe, New York.—Traces of iron color the otherwise milk-white crystals. They are rhombohedral in form, hard, and possess a bright lustre. The specific gravity is 2.84.

	PER CENT
SiO_2	0.45
Fe_2O_3	1.10
Al_2O_3	0.16
$CaCO_3$	52.16
$MgCO_3$	46.80
	99.76

24. Specimen from Guanajuato, Mexico.—The specimen is white, with visible traces of iron oxide. The crystals are hard and hexagonal in form. We were not able to determine the specific gravity.

	PER CENT
SiO_2	86.76
Fe_2O_3	5.50
Al_2O_3	4.33
$CaCO_3$	0.75
$MgCO_3$	2.11
	99.45

25. Specimen from Clayton, Iowa.—This takes a good polish and then it resembles brown marble. It belongs to the Platteville formation of the Ordovician system. The specific gravity is 2.69.

	PER CENT
SiO_2	0.87
Al_2O_3 and Fe_2O_3	1.01
$CaCO_3$	53.34
$MgCO_3$	44.44
	99.66

26. Specimen from Dubuque, Iowa.—It is of a gray color and quite compact in texture. It belongs to the same geological formation as the preceding.

	PER CENT
SiO_2	7.29
Al_2O_3 and Fe_2O_3	3.00
$CaCO_3$	46.94
$MgCO_3$	42.89
	100.12

27. Specimen from White Pine, Nevada.—The rhombohedral crystals are on a brown and gray surface, and are rather soft. The crystals on analysis were found to contain a small amount of copper. We were not able to determine the specific gravity.

	PER CENT
SiO_2	2.16
Fe_2O_3	0.00
Al_2O_3	24.24
$CaCO_3$	72.83
$MgCO_3$	0.31
Cu	0.86
	100.40

The specimen is in no sense a dolomite, but a limestone containing only a small amount of magnesium.

Professor LeRoy D. Weld has called our attention to "a soluble white incrustation sparsely deposited in some of the crevices in one of the Oneota dolomite caves on the Mississippi." The cave is situated near Marquette (North McGregor), Clayton County. On bringing to his laboratory and testing a portion of the incrustation, he finds it to be magnesium sulphate. Professor Weld accounts for this soluble sulphate by the action of sulphuric acid in the atmosphere on the magnesium carbonate of the rock. The cave is near the Milwaukee railway, and it is exposed to the smoke from the coal which usually contains a small quantity of sulphuric acid.

Cornell College, Mount Vernon.

THREE GLACIAL TILLS AT AMES, IOWA.

JOHN E. SMITH

The observations from which these data were obtained were made in an excavation opened for the basement of Wesley Foundation building just south of the athletic field of Iowa State College on Lincoln Way.

The uppermost deposit which is found everywhere on the upland in the vicinity of Ames, is the Wisconsin till, most of which at this place had been removed by erosion prior to the beginning of the work. A zone of red soil about two feet thick just beneath this till serves as an unmistakable indicator of the plane of separation between it and the Kansan till below.

The Kansan till varies from five feet to twenty feet in thickness which is about its regular variation in this vicinity. It is red at the top and varies through brown to yellowish below. The upper four feet of it does not effervesce in hydrochloric acid but the remainder of it is calcareous, though most of it shows the color of partly oxidized material.

Beneath the Kansan till, which covers a rough, eroded surface, is a firm, compact, blue clay containing pebbles, cobbles, bowlders and fragments some of which bear glacial striations. The materials of this till are all sizes and shapes and comprise many kinds of rock not found in the bedrock here, also fragments of wood, well preserved, and of coal. Many of the rocks of the till are un-

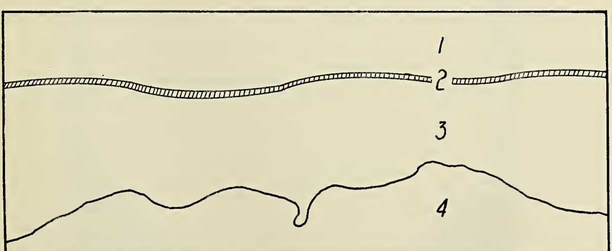


Fig. 1. 1, Wisconsin till; 2, Loess; 3, Kansan till; 4, Nebraskan till. The loess is not exposed in this pit. The contact between numbers 3 and 4 in the diagram is drawn to scale. Length of section, 40 feet.

weathered but some of them are crumbling from decay. The clay is dark blue when moist, a bluish gray when dry and is non-calcareous throughout. In this deposit on the east side of the pit, a globular pocket of fine sand was found. It is about four feet in diameter. Specimens of each of these materials were obtained for the college museum.

The irregular upper surface of this till, shown in the diagram, indicates a much eroded area in this vicinity at the time the Kansan glacier advanced over it. This till is believed to be the Sub-Aftonian or Nebraskan and is identical in appearance and description with one that has a much more even surface where it has recently been exposed in several other deep excavations made in this vicinity.

In a generalized section for this area, there are about eighty feet of Wisconsin till, five feet of loess, twenty feet of Kansan till above the Nebraskan till of which ten to fifteen feet are exposed.

State College, Ames.

DISCOVERY OF VOLCANIC ASH IN IOWA

CHARLES KEYES

Of all geological phenomena represented in Iowa those illustrating volcanic action are the rarest. Although we already know of the presence of very ancient lava-flows, which are disclosed in deep-well drillings, these are associated with rocks very much older than any outcropping in the state. These are the Keewenawan porphyries of the Northwest. From that very ancient date to the present there is not the slightest sign of volcanic activity discernible in all our very full geologic record. The finding, a short time ago, in the city of Des Moines, of very considerable beds of typical volcanic ash is therefore a circumstance of more than passing interest.

The ash is that pumaceous glass variety which, during violent volcanic eruptions, is thrown high in the air and wafted far abroad on the wings of the wind. The material is an impalpably fine dust. In the instance of Krakatoa, in the Straits of Sunda,

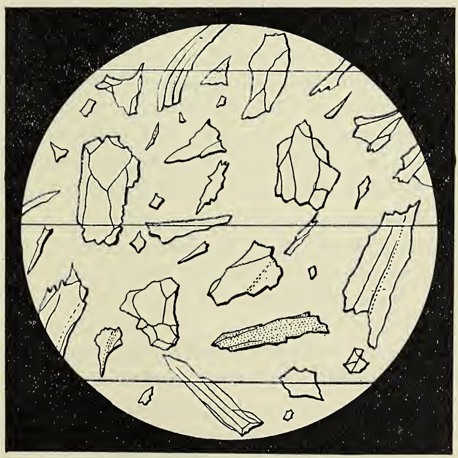


Fig. 2. Appearance of volcanic ash under the microscope.

in 1883, similar volcanic glass-dust drifted quite around the world, and produced the gorgeous "red sunsets" for many a month afterwards. Because of its abundance and of its thickness at Des Moines, it is not probable that the site of its origin is so far away as the other side of the earth. Most likely the material came from some of the later eruptions in the Rocky Mountains or the Pacific Coast ranges.

That the eruption which furnished the glass-dust for the Iowa deposit was a notable one, wherever it was, is clearly indicated by the depth and volume of the accumulation. In order to attain a thickness of six inches or a foot the dust-cloud from the volcanic vent must have been driven by a strong and prevailing wind.

No doubt a like thickness of ash spread over a very large expanse of country, probably over hundreds, and perhaps even thousands, of square miles. Except in especially favored localities this dust mingled with the soil and the record of its existence was lost. The deposit under consideration manifestly owes its preservation to the circumstances that the dust settled in a small pool of water where it remained undisturbed from further wind action and was fully protected from the erosive influence of the rains.

This notable volcanic ash bed is brought to sky in the course of recent extensive grade-cuttings on Fifth Avenue, between Grand Avenue and School streets, in the city of Des Moines. With it is also exposed one of the finest sections of Glacial deposits ever disclosed within the limits of our state. The longitudinal exposure is over half a mile, and the vertical cut is 50 feet as a maximum. It is essentially a north and south cross-section of West Hill, along a line about a quarter of a mile from the Des Moines river. The best ash sections are near the corner of Crocker street; and the formation is locally christened for brevity the Crocker Ash-bed.

The vertical section displayed at Crocker Corner is as follows:

7.	Soil, black loamy	Feet	2
6.	Till, yellow, bouldery, (Wisconsin)	Feet	10
5.	Sand, very fine, gray (volcanic ash)	Feet	1
4.	Loam, black, pebbleless	Feet	1
3.	Loess, yellow (Peorian)	Feet	15
2.	Till, dark red, bouldery (Kansan)	Feet	6
1.	Shale, variegated (Carbonic) exposed	Feet	4

The bed of the volcanic ash lies mainly in a shallow depression in the top of the loess. It is much disturbed and broken, a feature probably due to the plowing action of the Wisconsin ice. On the same horizon a few rods away is a bed of coarse gravel and small boulders containing numerous small logs of charcoal, which evidently were once drift-wood.

The occurrence of the ash-bed imediately beneath the Wisconsin till-sheet and directly upon the Yarmouth-Sangamon-Peorian loess, which was wind-formed, fixes the time of deposition as also interglacial—probably Peorian. This brings the date of deposition very close to us, geologically speaking.

In casting about for the location of the nearest possible source of such volcanic material we naturally look first of all to the Southwest which would be the direction of the prevailing winds. The nearest volcanic eruption of the violent kind that we know of is Mt. Capulin, in northeastern New Mexico. This is an ash cone whose magnitude far surpasses that of the famed Vesuvius. It is 3000 feet high and its crater is half a mile across. But Capulin is very recent. Its last eruption perhaps scarcely antedates the landing of Columbus on the western continent. There are other volcanoes in the Capulin field which might have served, for volcanic outburst there was continuous throughout Quaternary and part of Tertiary time. Spanish Peaks, in southeastern Colorado, seem too early in their last eruptions. Another possibility is the San Francisco group of volcanoes in northeastern Arizona, where more than 400 vents of all sizes and many dates occupy a circumscribed area. Volcanoes of the Pacific coast are all almost out of question.

Although this appears to be the first announcement of an occurrence of volcanic ash in Iowa it is perhaps not nearly so unusual a phenomenon as might be inferred. Now that the exact stratigraphic horizon is determined numerous other deposits may be expected to be speedily found. Because of the fact that the ash beds of the kind under consideration are eolian deposits their positions are unaffected by the ordinary means of deposition. Then, too, the determination of the exact age enables certain similar beds in Nebraska, as noted by Todd, [1] to be placed and correlated. With the western extension of these correlations we may confidentially expect at no distant day the tracing of the deposits to the exact vent of eruption.

The volcanic ash as seen under the microscope (figure 2) appears as sharp, angular fragments of clear, amorphous glass, wholly without trace of crystal structure. The dust is quite characteristic of the pumaceous glasses found in ash cones commonly built around volcanic vents. Associated with the glass-dust in the same

1 Science, Vol. VII, p. 373, 1886.

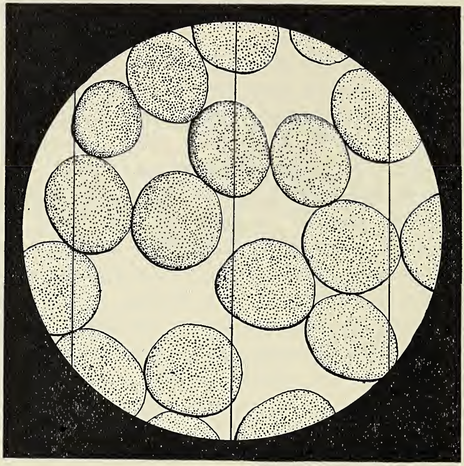


Fig. 3. Appearance of eolian sand under the microscope.

stratum are fine eolian sand grains, which are characterized by their minute size, remarkable uniformity and perfectly rounded form (figure 3). In the illustration the hair-lines are one-tenth of a millemeter apart. It is noted that the grains fall between one-twenty-fifth and one-fiftieth of a millemeter in their size. They are further distinguished from the glass of the pumaceous ash by being perfectly crystal.

The Fifth Avenue street cutting is represented in cross-section in figure 4. Noteworthy features aside from the presence of the volcanic ash-bed are the great loess deposit, designated as the Peoria Clay, and the basal till which is thought to be possibly the Nebraskan drift-sheet. The loess section probably represents continuous epirotic deposition during three interglacial and two glacial epochs, with great probability of its being deposited mainly during the last or Peoria epoch. Great stratigraphic significance is attached to this fact.

It is with some little doubt that the lowest drift deposit is referred to the Nebraska Till. The bed is quite distinct from the local Kansas Till; and the dark red coloration of the latter is sharply set off from the dark blue of the former. It may be a till even older than the Nebraskan. This suggestion arises from the fancy that there may be in Iowa several drift sheets antedating the oldest of which we now know.

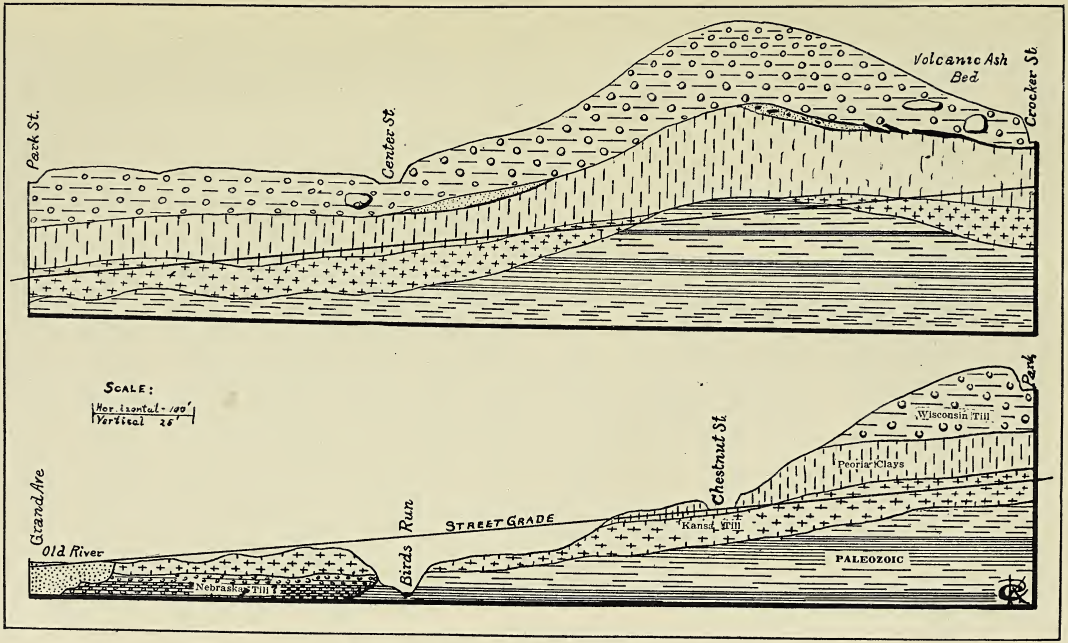


Fig. 4 Glacial deposits in Fifth Street grading, Des Moines.

GEOLOGICAL AGE OF THE TERREPLEINS OF UTAH'S PLATEAUX

By Charles Keyes

SYNOPSIS

Usually, genetically associated with the desert ranges the lofty Utah mesas belong not to the Great Basin province, but to an entirely different orographic type, the Colorado Dome. Upon the north flank of the latter they recline as remnantal patches of great sections of soft deposits which elsewhere have been completely stripped off the indurated Paleozoics that constitute the foundation of the broad arch. The High Plateaux appear to owe their belated preservation to Tertiary extravasation of lavas that serve as protecting caps for the unconsolidated strata beneath. Were it not for these remnantal tablelands long and exciting chapters in the history of the Cordilleran region would be lost beyond possible rescue.

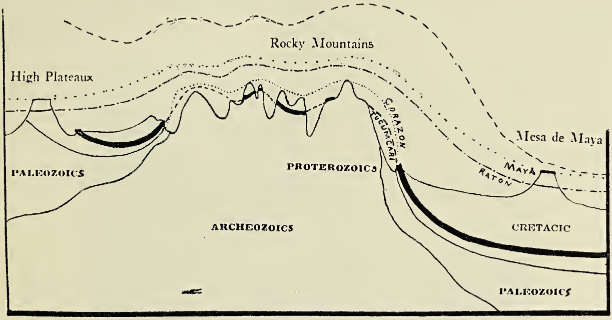


Fig. 4a

Like so many of the neighboring Great Basin ranges the High Plateaux stand 11,000 to 12,000 feet above sea-level, and 5,000 to 6,000 feet above the valley floors between — the present general plains surface. Comprising as they do, a dozen or more lofty eminences, they have flat-topped summits of such limited extent that they now are really narrow mountain ridges not essentially distinct from the other desert ranges. They differ from the ranges of the Great Basin lying to the west only in the circumstance that the remnantal lava sheets which surmount them still preserve traces of the original high plains surface, whereas the mountain blocks not so protected, comprising the other desert ranges, do not.

Because of the light which they recently shed upon the physiographic development of the arid part of our continent the High Plateaux of Utah possess unusual interest. Strangely they give a clue to the origin of the bare desert ranges to the west of them, and to the forest clad chains to the east. Arid Great Basin Range and pluvial Cordillera thus really evolve along parallel lines. The Utah heights not only connect the mountains of two climatic contrasts, but they carry westward the regional diastrophic record so clearly decipherable in the east, and indicate a succession of geographic cycles which the Great Basin has no doubt passed through but of which it has now no other intimations.

In the High Plateaux region there appear to be presented in the post-Paleozoic section five distinct, wide-spread, and notable horizons of unconformity which represent erosion intervals of vast duration and intensity. Their stratigraphic positions coincide exactly with similar erosion plains in the rock-column on the east flank of the Rocky Mountain uplift. These levels are also traceable around the southern extremity of the Cordillera, so that their identifications are seemingly fixed beyond peradventure.

Age	East Side, r.m.	r.m. Crest	West Side, r.m.
Present	General plains surface	Stream valleys	Plains surface
Miocene	Maya	Obliterated	Markágunt
Laramie	Raton	Obliterated	Aquarius
Comanchian	Corazon	Summital	Paunságunt
Jurassic	Tucumcari	Central monadnocks	Rafael

BATHOLITHIC VEININGS OF THE SIERRA DE LOS CUCARAS IN BAJA CALIFORNIA

CHARLES KEYES

(*ABSTRACT*)

The Sierra de los Cucaras is a long, little dissected cuesta the escarpmental axis of which trends northwestward from the head of the Gulf of California. At the crest overlooking the vast,

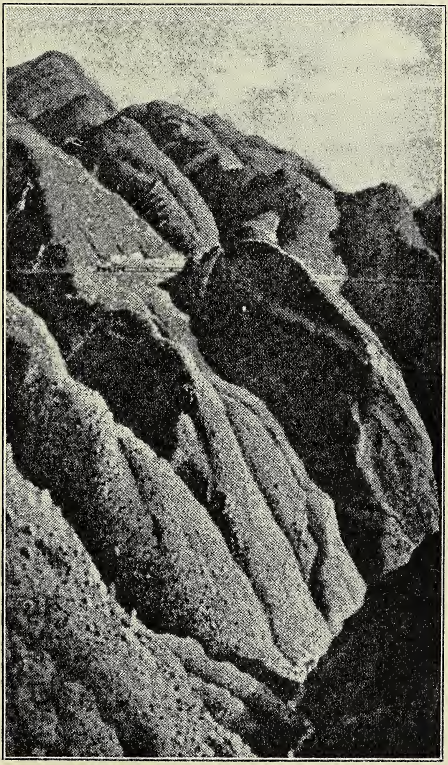


Fig. 5. Carisso gorge, Baja California.

smooth lowland to the eastward its summital plain is about 4000 feet above tide. On the northeast the uplift rises abruptly out of a widespread desert lying below sea-level, the Mexican extension of the Imperial Valley, recently reclaimed extensively to garden purposes through irrigation.

The central massif is a granitic type of rock not so very unlike that of the Sierra Nevada farther north. This granitic core is conspicuously jointed after the usual manner of large granite masses, but the joint planes differ from the common occurrences of this kind of structure in that the faces of the ruptures are separated widely and the intervening spaces are filled with white, aphanitic, or quartz-like material, which produces a wonderful highly contrasted network. It is veining on a colossal scale, the joint plates being two to six feet across.

Toward the north end of the mountain range the titanic crazing is displayed in superb sections 1500 feet high in the famous Carisso Gorge near the United States boundary. The characteristic effects are well represented in the accompanying photographic view (figure 5).

SOME PLEISTOCENE EXPOSURES IN DES MOINES [1]

JAMES H. LEES

In the early spring of 1921 as the writer was examining the face of the bluff bounding the north side of the Des Moines valley just below the Capitol grounds he noticed, on the west side of the entrance to a ravine between Southeast 13th and 14th streets, where the State operated a small drift coal mine for some time, a section of Pleistocene material above the Coal Measures sandstone, which seemed to present features of some interest. Closer inspection showed the probable presence of two drift sheets and since the superposed evidence of successive invasions of the continental glaciers always excites curiosity it may be worth while to record this bit of evidence here.

Overlying the sandstone and shale of the Coal Measures, which rise twelve feet above the railway tracks, is a four foot layer of pebbly till, which is red below and partly gray and calcareous in the upper foot. Over this till, which probably is Kansan in age, is loess, which is gray and hard in the lower foot or two, but yellowish and softer above. A small gully which has been cut through the loess shows fossil shells. Lime concretions are abundant throughout the loess and a few sand grains, some of them as large as one-eighth of an inch in diameter, were seen in the basal portion. The loess must be seven feet thick as exposed here at the point of the bluff. The overlying material is not well exposed but it is pebbly and probably is Wisconsin till since this is known to be present over Capitol Hill, as at the exposure next to be described.

In the fall and winter of 1915 a rather deep cut was made along East Court Avenue between 10th and 12th streets for the purpose of giving an easier grade to and through the enlarged Capitol grounds. The exposures made at that time were closely watched by the writer and were reported in detail in volume XXIII of these Proceedings. However, it seems well to discuss them here in connection with other exposures in the general region. It chanced that this cut included two of the spots described by McGee and Call in their classic paper published in 1882 in

[1] Published with permission of the Director of the Iowa Geological Survey.

volume 24 of the American Journal of Science and so gave opportunity to verify and extend their sections. These sections (3 and 4) included drift clay overlying loess, on both sides of Court Avenue, between 10th and 11th streets. Their sections 1 and 2, on East 9th Street between Walnut and Court, showed loess over "vermillion-red clay containing a few pebbles of shale, 1 foot." This clay rested on Carboniferous shale and was stated by them to be "the product of disintegration in situ (preglacial) of the subjacent shale." It is worthy of note that nowhere do these men claim to have found a glacial drift beneath the loess. And it should be noted further that when the grade of Court Avenue was lowered in 1915 no subloessial drift was revealed, even where the cutting was extended downward into the shales of the Des Moines series of the Pennsylvanian. Only the drift sheet of the Wisconsin stage was present, overlying a thick body of interglacial loess, which in turn rested unconformably on geest, residual, plainly, from the underlying shale. In view of recent statements that McGee and Call's section included "Till; dark red clay with abundant pebbles—6 feet" and that "the south abutment (of the Court Avenue viaduct) rests on the more remote drift sheet," (the Kansan) (Annals of Iowa, July, 1920) careful attention surely should be paid to the facts as stated by McGee and Call and by Lees in the articles cited.

The widespread extent of the Peorian loess over Capitol Hill at the time of the Wisconsin ice invasion is indicated by its being reached under twenty feet of Wisconsin pebbly till in the excavation for the new State House heating tunnel on East Grand Avenue at 12th Street, as well as by a similar discovery in the excavation for the heating plant for East High School, one-fourth of a mile northeast of the State House. It has been reached also in the lower ground to the north.

A section which is in some respects of more interest than those already discussed, owing to its greater completeness, is an artificial cutting on West 5th Street. Here are to be found in fine development the Kansan till, the Peorian loess and the Wisconsin till. At Chestnut Street, where the cut begins, there was to be seen in November of 1920, above a variegated Coal Measure shale a yellowish bowldery till which was six to ten feet in thickness. Upward it graded into a red-brown sticky clay which for the most part contained but a few pebbles and these very small, although locally pebbles were more abundant. Where this till was dry it was hard with a starchy fracture. Both the red and yellow phases were non-calcareous. Possibly this till was derived in considerable part from the underlying shale. The upper red portion evidently is nearly at the gumbotil stage of weathering. This phase showed a thickness of seven feet.

There seems to be no sufficient reason or necessity for considering the older till in this cut as being other than Kansan. There is nothing in its stratigraphic position or its physical characters which is in any sense determinative. Experience has abundantly proved that there are no physical criteria which will differentiate between Kansan and Nebraskan tills. Neither color nor texture nor pebble content offer conclusive testimony. Till has been found which is known from its relations to be Nebraskan and yet it is as light a gray as socalled "typical Kansan till," and has similar structure and pebble content. The converse is equally true—instances could be cited of till positively known to be Kansan which is dark gray to black and not more pebble-bearing than Nebraskan till. The abolition of the very comfortable criterion of physical character throws the geologist back into the realm of uncertainty unless he can substantiate his claim by stratigraphic methods, such as the presence of gumbotils or soil bands. In the present case we can only say that there is nothing to indicate that this till is older than the Kansan, since, be its color blue, yellow, or brown, that is merely a matter of oxidation and this may transpire with equal readiness in one till or in another.

In the vicinity of Chestnut Street the upper surface of the Kansan is practically level but between Center and Crocker streets is a small knoll of this till which rises about fifteen feet above the level of the till at Chestnut. About five feet of brown, pebbly till with starchy fracture is exposed at this point in the cut. Some fresh red granite bowlders are present at the surface of the till.

Over the Kansan till and exposed along almost the entire extent of the cut, about six blocks, is the loess, which in places has a thickness of fifteen to eighteen feet. It is chiefly of the yellow phase, although in places there is three or four feet of gray at the top and this is locally marked off at the base by a ferruginous band which seems to mark a former water surface. In places fossils are common in the yellow loess while red "pipe-stems" abound in the gray variety. Both phases are calcareous.

In the vicinity of Crocker Street there are in the upper portion of the loess several small sand lenses about four feet long and six inches thick. They are tilted to the north and are surrounded by the gray loess except where they rise to the surface of this stratum and come in contact with the overlying till. These lenses were stated by Dr. Charles Keyes in conversation to be largely volcanic ash, and this may indeed be true, since ash beds are known elsewhere in Iowa and neighboring states. Most conspicuous, perhaps, in our own state is the two foot bed exposed at several points in the northern part of Harrison county near the village of Little Sioux along the east bank of Little Sioux river. While the presence of this ash bed was known to science previously it was only after repeated examinations of its outcrops during the season of 1921 that Dr. Geo. F. Kay felt justified in forming the judgment that the evidence warrants the interpretation that the volcanic ash is contemporaneous with the loess. The evidence of this judgment will be presented by him in a forthcoming publication. According to this interpretation, then, the relationships of this ash bed would be similar to those of the lenses in the Des Moines cut —both would be related to the Peorian loess. Samples of the Harrison county ash in the office of the Iowa Geological Survey show it to be almost white with a finely gritty feel.

Above the loess is Wisconsin till, which on the average is six feet thick. In most places it is weathered through its entire thickness to a brownish joint clay. It is very characteristic in bearing numerous bowlders and cobblestones, many of which are limestone.

The sections described above, as will have been seen, are quite normal in their main aspects, and in so far may be duplicated in many other localities. Some of them present slightly unique phenomena, such as the ash bed on 5th Street and the intermingling of fossiliferous loess and pebble-bearing till in the Court Avenue cut. These features as well as their normal characters perhaps make them worthy of mention as illuminating the complex record of the Pleistocene epoch in the Mississippi valley and the large part our state must play in the unfolding of that record.

They are of value in another way and that is in what they show of the physiographic history of this region. We know that an immense interval must exist between the deposition of the Coal Measures and the advance of the glaciers of Pleistocene time. During this interval several successive topographies were incised into the face of Iowa, only to be repeatedly wiped off as a schoolboy wipes his slate, or did when he had one. But of the Pleistocene topography we can form some definite ideas. Following the retreat of the Nebraskan ice-sheet and the development of the Nebraskan gumbotil a system of streams must have been deeply carved into the unconsolidated glacial deposits and in many cases into the underlying Paleozoic strata. Such was the case at Des Moines and it resulted in the formation of a deep broad valley from whose slopes apparently much of the till was removed. The Raccoon river must have been a stream of large importance in those days as now, for the wide valley south of the State House originally belonged to that stream. Again after the recession of the Kansan glacier a similar sequence of events occurred. Before the loess was deposited the old valleys had been re-excavated, or new ones formed, and the Kansan till had been swept away from some parts of the surface, permitting the formation of several feet of geest from the shales of the Coal Measures. The loess still formed a blanket to the valley's edge when the Wisconsin ice covered the region, and protected it from further weathering or erosion. To the south of the river the loess still forms the surface covering. It is of interest to note here that in the early part of 1921 an elephantine tusk measuring nearly ten feet in length was found buried in the loess in the south part of Des Moines. It is certain then, that its owner was roaming over the Iowa prairies as recently as Peorian time, during the period in which human beings have been living, in the Old World at least, if not in the New.

Iowa Geological Survey

SOME PROBOSCIDIAN REMAINS FOUND IN HENRY COUNTY

H. E. JAQUES

Rather frequent discoveries of the remains of at least two species of the extinct elephant-like animals which inhabited this continent during the Pleistocene have been made in Henry county. These specimens have been found in several parts of the county, and have usually been limited to tusks and teeth. A number of bones have been found but in most cases in such condition as to

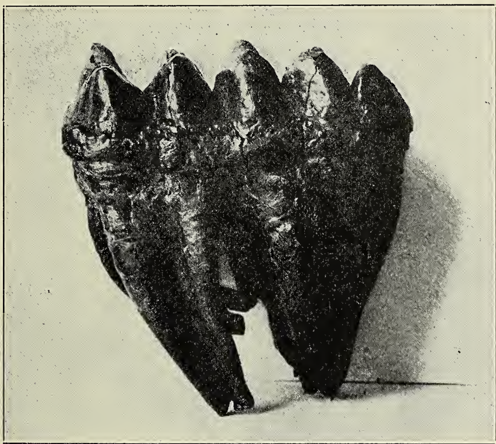


Fig. 5a. Tooth of *Mammut Americanum.*

make identification difficult. At least two of these finds are sufficiently noteworthy to deserve some permanent record.

The Mastodon tooth (Fig. 5a) was found during the digging of a shallow well less than a mile east of Mount Pleasant (Section 14, Twp. 71 N., Range VI W.) at what was known as the "Ross Spring." This tooth is apparently the third molar of a mature animal of the species *Mammut americanum.* It measures eight

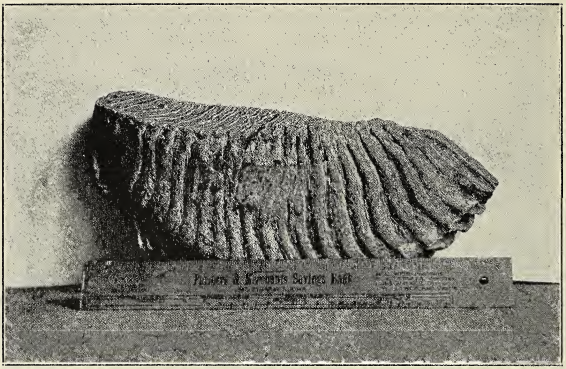


Fig. 5b. Lower right molar of *Elephas Columbi.*

inches in length by four and one-half inches in width and, in its present condition with the tips of the roots broken off, eight and one-half inches in height. It weighs almost six and one-half pounds. At the same time and place were found three unidentified pieces of bone, a vertebra, a femur with the ends broken off and lost and two small tusks measuring 24 4/5 and 26 3/4 inches

Fig. 5c. Upper right molar of *Elephas Columbi.*

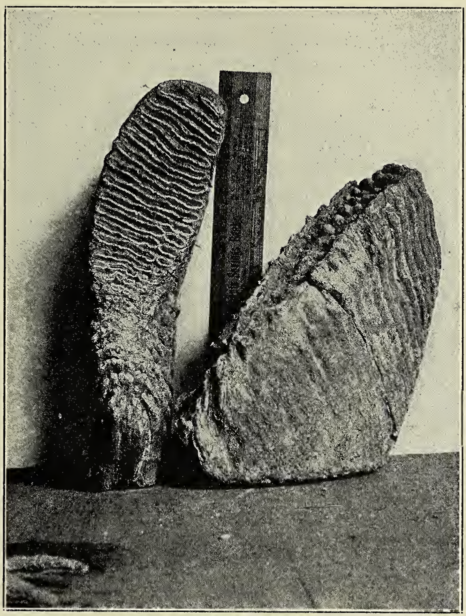


Fig. 5d. Lower and upper right molars.

in length respectively and 3 1/4 inches in diameter. The tusks weigh about 8 3/4 pounds each.

It would seem that the spring might have been a watering place for these and other animals and that the one or more specimens represented by these remains had lost their lives by fighting, or miring down.

Other mastodon teeth have been found near Salem and northwest of Mount Pleasant in the neighborhood of Trenton.

During the summer of 1920 in a little creek a short distance south of Trenton (Section 10, Twp. 72 N., Range VII W.) the two teeth shown in figures 5b, c, and d were found by H. F. Elliott, the specimens having been uncovered by a recent rain. They are teeth of *Elephas columbi,* an elephant of the Pleistocene which rivaled in size our present day African elephant. The one shown in figure 5b is a lower tooth of the right side, the other (Fig. 5c) is an upper tooth, also from the right side. Both are the hindermost; the last ones that the animal would have acquired. He was well along in life, but not aged. The upper tooth measures 13 1/4 inches by 8 inches by 3 1/2 inches and weighs a little over 12 1/4 pounds. Its companion measures 14 inches by 6 1/4 inches by 3 1/2 inches and weighs almost 12 pounds. All of these specimens are now in the Museum of Iowa Wesleyan College.

Mr. J. H. Kephart has in his possession the enamel crown of a Mastodon tooth very much like that shown in figure 5a but about one-half inch smaller, which he found September, 1921, in Sugar creek northwest of Trenton in Section 33, Twp. 73 N, Range VII W.

Iowa Wesleyan College
Mount Pleasant, Iowa

A LABORATORY OPTICAL PYROMETER:

NOTES ON ITS DESIGN AND OPERATION

WM. SCHRIEVER

The writer was confronted with the problem of measuring the temperature of a tungsten wire enclosed in an evacuated tube. A thermocouple could not be used because it would be certain to apply unknown torques to the wire and also to disturb the temperature distribution along the wire. An optical or radiation method of temperature measurement would overcome both of these difficulties. An optical pyrometer suitable for accurate temperature determinations and flexible enough to be of general use in a physical laboratory is not on the market at the present time. This led the writer to the task of designing and constructing the instrument described in this article. For the benefit of those who are not familiar with optical pyrometry a brief sketch of the theory and design of a Holborn-Kurlbaum optical pyrometer has been included.

GENERAL THEORY

In figure 6 is shown a schematic diagram of a Morse or Holborn-Kurlbaum type optical pyrometer.[1] *A* is the background filament whose temperature is to be determined, *B* is a lens which forms a real image of *A* at *D, C* and *E* are limiting diaphragms, *D*

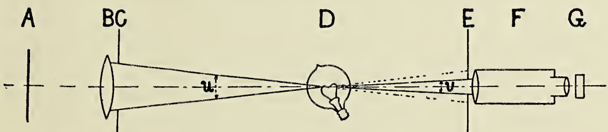


Fig. 6. Schematic diagram of Holborn-Kurlbaum type optical pyrometer.

is the pyrometer-lamp, *F* is a telescope focused on *D* and the image of *A, G* is a monochromatic screen. In making a temperature determination the current thru *D* is adjusted so that the filament of *D* disappears against the image of *A*. Then the temperature is read from the current-temperature calibration curve of the pyrometer.

The calibration of the pyrometer is effected by replacing *A* by a "black-body furnace" [2] maintained at a temperature which can be measured with a gas-thermometer. (The gas-scale has been extended by Day and Sossman to the melting points of gold and palladium which they found to be 1335.6°K and 1822.5°K respectively.) With the aid of Wien's Equation,

$$E_L = C_1 L^{-5} e^{-C_2/LT},$$

where E_L is the energy of wave-length L radiated by a black-body at a temperature of T°K, C_1 and C_2 are constants, and e is the base of Neperian logarithms, the calibration can be extended to higher temperatures.

Suppose some sort of an absorbing screen, which transmits a fraction t of the radiated energy, is placed between A and D, and that the body is at an unknown temperature S°K. Wien's equation for this body is

$$tE_0 = tC_1 L^{-5} e^{-C_2/L S_0}.$$

Also suppose that a black-body at a temperature of S°K (within the range of the gas-thermometer) appears equally bright through the pyrometer when it is not viewed through the absorbing screen. Wien's equation is

$$E = C_1 L^{-5} e^{-C_2/LS}.$$

Now since $E = tE_0$ we have

$$\mathrm{Log}_e\ 1/t = C_2\ (1/S - 1/S_0)/L$$

in which S_0 is the only unknown; the present accepted value of C_2 is 14320 micron degrees.[15] Thus with this relation available the black-body furnace may be maintained at a constant temperature — the melting point of gold, for example — and any number of points for the current-temperature curve may be obtained by using absorbing screens of various transmissions; of course these points will all correspond to temperatures below 1336.5°K. After this part of the curve has been plotted, it can be extended in the manner described in the first part of this paragraph.

In general a hot body does not emit as much energy as a black body at the same temperature [2], [10], nor is this fractional emission the same for all bodies. For example, a stick of carbon emits much more energy than a piece of polished platinum at the same temperature. In this case, if a deep hole of small diameter be present in the carbon stick and a similar one in the piece of platinum, the holes will appear equally bright and will be as bright as a black-body at the same temperature. Suppose the platinum at a temperture T°K is emitting a fraction r of the energy that a black-body would emit if it were in the same thermal state, and let S be the temperature of a black-body which appears as bright through the pyrometer as the radiating platinum. Then if E be the energy of wavelength L emitted by each,

$$E = C_1 L^{-5} e^{-C_2/LT} \,.\, r$$

and

$$E = C_1 L^{-5} e^{-C_2/LS}$$

Equating the right-hand members, we have

$$r e^{-C_2/LT} = e^{-C_2/LS}$$

or

$$1/T = 1/S + \log r \,.\, L/C_2.$$

Since the hole in the platinum is emitting like a black-body, its temperature determination will yield the true temperature of the platinum. The temperature S may be found in the usual manner and, by means of the above equation, r may be calculated. The number r is called the "emissivity" of the substance.[3,14]. It varies from substance to substance and with the condition of the surface for the same substance, as well as with the temperature and with the wavelength of the light used in its determination. When r is known and S has been observed, T can be calculated. Thus we have a method for determining the true temperature of a non-black-body.

THE OPTICAL PYROMETER IN PRACTICE

The objective lens, B of figure 6, should be an achromatic lens of good quality. A rapid rectilinear photographic lens having a focal length of about 25 cm, and a maximum aperture of about F.8 mounted in a barrel with an iris-diaphragm, will serve very well. It should be placed at such a distance from the pyrometer-lamp D that the image of the background A formed at D is much larger than the filament of D.

The telescope F is the eyepiece of the pyrometer. It should be of good quality and capable of being focused on objects as near as one meter. The magnifying power should be sufficiently large so that no difficulty is experienced by the observer in fixing on the intersection of the pyrometer-filament and the background image. The resolving power of almost any laboratory telescope is so great that the objective lens (of the telescope) will need to be stopped down with a limiting diaphragm E. When the resolving power is too great, dark bands are seen on either side of the pyrometer filament; these are caused by the diffraction of the light by the filament. Such diffraction-bands make it almost impossible to get an accurate brightness-match. A telescope having an objective lens of 25 cm. focal length and an eyepiece of 18 mm. focal length will be found satisfactory.

The limiting diaphragms *C* and *E* must be of such a size that disappearances of the pyrometer-lamp filament against the background-image are possible. Angle v must be smaller than angle u. Both *C* and *E* should be as large as possible but their size must be consistent with ability to obtain disappearances—in order to minimize the diffraction effects at the edges of the apertures, and they should be as far from the lamp *D* as possible. A stop *E*, which may be just small enough to be satisfactorily used at the lower temperatures, may prove to be too large when making brightness-matches at the higher temperatures. The larger *E* is, the farther down the temperature-scale can be extended. Therefore it will be well to use at least two different stops when making the complete calibration of a pyrometer.

A pyrometer lamp having a tungsten filament in a spherical bulb 5 cm. in diameter will be found very satisfactory. The filament of such a lamp is usually in the form of a hairpin loop with a small kink at the top of the loop. This kink is useful in that it enables the operator to be certain that he is using the same part of the filament at all times. A lamp having a filament of 0.033 mm. in diameter is useful if the temperature of small objects, such as wires, is to be measured; for larger objects a larger filament will be found more satisfactory. The diameter of the lamp filament should aways be considerably smaller than that of the background-image. When measuring the temperatures of wires it should be remembered that Lambert's Cosine Law of Emission does not hold in general.[16] For example, a tungsten wire appears brighter at the edge than near the center, while the reverse is true for a carbon lamp filament. Consequently, for most accurate work, the pyrometer-lamp filament should be placed parallel to the background-image. If the background-image is large and the brightness-match is made at a point near its center, the filament may be placed so as to cross the image. For most purposes sufficient accuracy will be obtained even though the filament and image are crossed and the image is not large.

The objective lens of the pyrometer, the kink of the lamp filament, and the telescope must be very approximately axially aligned. Therefore provision should be made for a vertical adjustment and for a rotational adjustment about a vertical axis for the lens, for the telescope, and for the lamp. It must also be possible to rotate the telescope through a small angle in a vertical plane through the optical axis of the system; the lamp should be capable of being adjusted in a horizontal direction perpendicular to the optical axis of the system.

After the pyrometer has once been calibrated the relative positions of the parts must remain fixed, otherwise the temperature determinations will be incorrect. It is, however, allowable to move the different parts relatively to one another if the angles u and v are kept the same. Usually it will be found more convenient to recalibrate the instrument than to make adjustments which will keep u and v constant. The focusing of the pyrometer on the background should be accomplished by changing the distance between A and B.

Absolutely-monochromatic screens for use at G cannot be obtained, and filters which are very nearly monochromatic transmit so little light that they can be used only in measuring the high temperatures. "Partially-monochromatic" glasses, which absorb so little of the incident energy that they are usable even at relatively low temperatures, are available. Such a filter can be employed if the correct one of all the transmitted wavelengths is selected. This wavelength is called the "effective-wavelength[3,4] of the filter. It is such that, for any definite temperature interval for a particular source, the ratio of the radiation intensities for this wavelength is equal to the ratio of the integral luminosities through the screen used. The effective wavelength of a filter varies with the temperature to be measured, but for most work, if the average value is used, the error will not be too large. For example, an error of 0.001 micron at 2400°K would cause an error of about 1.2° and at 3000°K an error of about 3° if the filter transmitted red light. Filters transmitting red light are most convenient for general use since red light of a sufficient intensity is emitted by a hot body at a lower temperature than that at which light of the shorter wavelengths is radiated. The least relative change of brightness which can just be detected is about the same for red as for blue light but the change in intensity for a given small temperature change of the radiator is greater for blue than for red. Also, diffraction effects are less troublesome when one is using light of the shorter wavelength. Therefore greater accuracy is obtainable when light of shorter wavelengths is used, but the lowest measurable temperature is higher.

Perhaps the most convenient form of absorbing screen to be used between A and D is a rotating "sectored-disk."[4] Disks which allow as little as 1/180 of the incident light to pass through (2° opening) can be very satisfactorily employed. The disk should be placed as near the pyrometer lamp as possible.[5] If it is located near the lens the definition will be bad because of diffraction, and it will be especially bad if the opening of the disk is small and parallel to the background image (as the opening passes through the optical axis of the pyrometer) if the background is a wire. Therefore it is also advisable to have the opening perpendicular to the background when the opening is passing through the optical axis. The transmission of a sectored disc is the same whether the opening is all in one sector or is made up of several smaller sectors the sum of which is equal to the single sector. The transmission is also independent of the speed of rotation of the disc but the rotation must be sufficiently fast to prevent a flicker. Flicker is not only disagreeable for the observer but it also makes the obtaining of brightness-matches an impossibility.

Black-body furnaces are not easily set up, so it is often much more convenient and satisfactory to obtain a calibrated "Standard-Lamp" for which a curve connecting current through lamp filament and brightness-temperature of filament is furnished. This lamp is to be used in place of the furnace. It is usually a lamp having a large filament which requires a large current at a low voltage. In practice the current must be very accurately determined; this is easily done with a standard resistance and a potentiometer. If the effective-wavelength at which the standard-lamp is calibrated happens to be different from the effective-wavelength of the filter G of the pyrometer which it is desired to calibrate, a correction must be made; that is, the brightness-temperatures at the given effective-wavelength must be changed over into brightness-temperatures at the effective-wavelength of the pyrometer filter. This can be done by means of the formula [6,7]

$$1/S_2 = L_2 \ (1/S_1 - 1/T_c)/L_1 + 1/T_c$$

where S_1 and S_2 are the brightness-temperatures at the effective-wavelengths L_1 and L_2 respectively, and T_c is the color-temperature. If the standard-lamp has a tungsten filament this change can be easily made since the color-temperatures with the corresponding true-temperatures have already been worked out.[8, 9]

Sometimes, perhaps generally, in laboratory work, a glass window, the wall of a glass tube, or a layer of some transparent medium is present between the source whose temperature is desired and the pyrometer. Since such media absorb some of the incident light it is necessary to correct for their absorptions before the true brightness-temperature of the source can be stated. If the absorbing medium is on such an apparatus that it is possible to put a small incandescent lamp behind the medium, then the temperatures of the lamp for fixed currents can be determined through the absorbing medium and without the medium present. From such data the temperature-corrections may be found for the desired range. If the apparatus is in the form of a closed glass tube it can be placed in the usual position for the sectored-disc, its transmission determined, and the corrections calculated.[11], [12], [13]

Currents through the pyrometer-lamp filament must be accurately known. A potentiometer gives the highest accuracy but, if a number of settings are to be made, the time required is rather long. Therefore a deflection potentiometer is used for the highest grade work. For ordinary purposes a high grade ammeter equipped with an external adjustable (by steps) shunt will be found very satisfactory. The steps should be so chosen that it will always be possible to keep the deflection of the pointer between 100 and 120 on a 150-division scale. The variable resistance to be used in the pyrometer-lamp circuit should be capable of rather fine adjustment. This is readily accomplished by connecting two rheostats of the sliding-contact type in parallel; one should have a resistance of about three times that of the other. The rough adjustment is made on the rheostat of low resistance and the final adjustment on the one of high resistance. Best results will be secured if the adjustment is always made in the same manner, as for example, the brightness-match might be made by gradually increasing the current until the filament disappears against the background-image. If all the settings are made in this manner consistent results can be obtained with a minimum of experience.

A LABORATORY OPTICAL PYROMETER

Figure 7 shows an optical pyrometer which meets all the conditions listed in the preceding section of this article. It also has a number of adjustments which help make it flexible enough to be of general use in a physical laboratory.

The objective lens *A* is a Bausch & Lomb rapid rectilinear lens having a diameter of 28 mm., and a focal length of 21 cm. Between the two lens-combinations is an iris diaphragm which, when set at the largest aperture, allows the lens to have a speed of U. S.4.

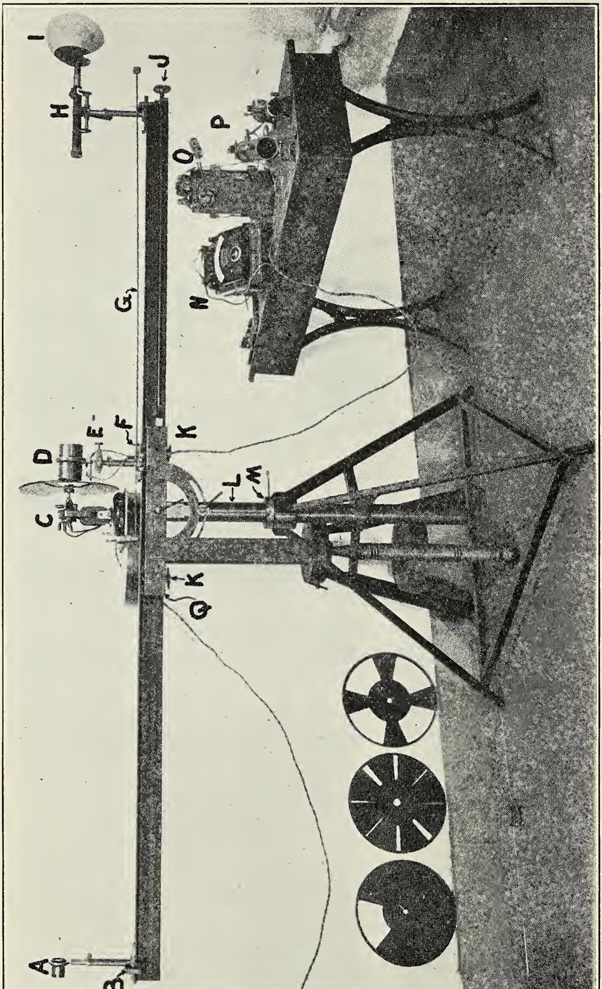


Fig. 7. A Holborn-Kurlbaum optical pyrometer designed so as to be of general use in a physical laboratory.

The telescope *H* was obtained from Wm. Gaertner. The objective lens of this telescope is 30 mm. in diameter and it has a focal length of about 25 cm. It is furnished with two eyepieces, one of 18 mm. and one of 25 mm. focal length. The shorter focal length eyepiece is to be used with fine pyrometer-lamp filaments. In the lens-cap is a 15 mm. hole, the edges of which are beveled on the inside. This serves as the diaphragm *E* of figure 6 for the lower temperatures. At medium and high temperatures this stop is too large, hence three brass discs, which fit snugly in the cap are provided. These have apertures of 13 mm., 10 mm., and 8 mm., respectively. The disk having the 13 mm. hole proved to be the most useful one for the setting shown in figure 7.

Two pieces of red glass, each 1 cm. in diameter and 5 mm. thick, mounted in brass housing, form the monochromatic screen, *G* Fig. 6. The effective-wavelength of this screen, between 1200 and 2400°K, is 0.658 micron. The colored glasses together with effective-wavelength calibration data were obtained from the Nela Research Laboratory of the General Electric Company, Nela Park, Cleveland. The brass housing is equipped with three spring-brass fingers which hold it in place on the eyepiece of the telescope. The black cardboard shade *I* keeps light, other than that coming through the telescope, from entering the operator's eyes. It enables the observer to keep both eyes open, thus making the observation less tiresome.

Telescoping-tube standards allow the objective lens and the telescope to be adjusted vertically and to be rotated about vertical axes. The telescope rests in the two V-shaped pieces of an ordinary laboratory telescope-clamp. In each arm of the rear 'V' is a thumbscrew. These thumbscrews make possible the small adjustments which are usually necessary to bring the axis of the telescope in coincidence with the optical axis of the pyrometer.

The pyrometer-lamp is mounted on the standard shown at D in figure 7. It is inside of the black cylindrical tube which prevents reflection of light from the outside of the lamp-bulb. Figure 8 shows the standard more in detail. The white porcelain lamp-socket is screwed to a round brass disc which is held in a recess in the square base-plate by two spring clips; this permits the lamp to be turned about its axis until the filament is perpendicular to the optical axis of the pyrometer. The square base-plate is fastened to a ring *R* which slides on another ring *S* to which it is held by two spring clips. The ring *S* stands on a plate which can be moved horizontally by turning the knurled head *E*. The rings make it

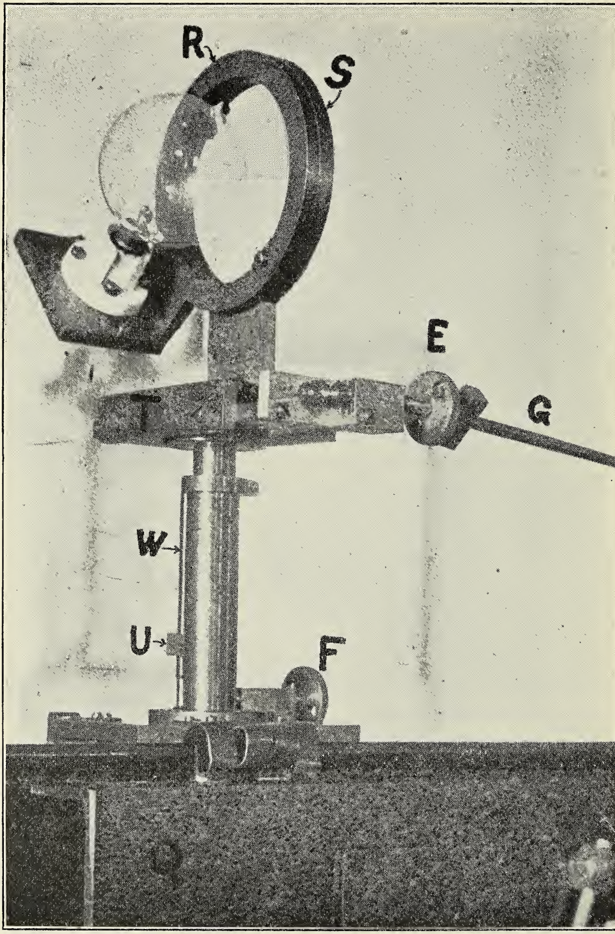


Fig. 8 Mounting for the optical pyrometer lamp which permits of horizontal and vertical adjustment by the observer while he is looking at the filament through the telescope.

possible to rotate the lamp about the optical axis of the pyrometer; with this motion the filament may be set at any angle with the background-image. Vertical motion of the lamp is obtained by turning the knurled head *F*. This turning actuates the screw *W* in the nut *U* which is attached to the center-post supporting the table *T*. With these horizontal and vertical motions it is possible to set the kink of the pyrometer-lamp filament in the optical axis of the instrument.

The bed of the pyrometer is made of a piece of angleiron 2 inches wide by 3 inches high by 8½ feet long. The top and back surfaces (in the picture) are machined. A channel running the full length of the bed at a distance of 3/16 inch from the top, furnishes the place for attaching the hook-clamps, like *B* of figure 7, which hold the lens and telescope standards in position. The clamp *B* is so constructed that, when the thumbscrew is tightened, the clamp not only pulls downward but also exerts a horizontal force which brings the guides, attached to the base of the standard, against the machined surface of the bed; this keeps the parts in alignment. The pyrometer-lamp standard is secured by means of suitable spring-fingers.

To the bed are attached two studs which slide in slots in the top of the piece *Q*, Fig. 8, thus allowing the bed to slide parallel to itself. This motion is produced by turning the knurled hand-wheel *J*, Fig. 7, It permits the operator to focus the pyrometer on the background while he is looking through the telescope. The bed may be locked in place by tightening the thumb-nuts *K*. With the forked rod *G* the observer may make the vertical and horizontal adjustments of the pyrometer-lamp while he views the filament through the telescope. This rod *G* makes the aligning of the parts a simple operation.

The post *L* supports the bed of the pyrometer. It is made of a piece of heavy iron pipe 2¼ inches in diameter which has square threads of ½ cm. pitch on the outside. By turning the nut *M* the bed may be raised or lowered, the maximum range of the motion being 18 inches. The nut may be locked in position by screwing in the handle, thus permitting rotation of the bed about a vertical axis without there being any danger of having the post turn in the nut. From figure 7 it is also seen that the bed may be tilted so that the observer may view the backgrounds either up or down at an angle. These adjustments give the instrument the flexibility which is necessary for general laboratory work. The tripod base is very rigid and stable; it is made of one-inch angleiron bolted to the two cast-iron guides through which the post *L* passes.

The motor with the sectored disc attached is shown at *C*, figure 7. The motor is supported by a laboratory stand which at no point is in contact with the pyrometer. The motor cannot be attached to the pyrometer on account of the vibration which it is almost certain to produce. Some additional sectored-discs are shown in the figure. By using combinations of two discs, sectors having various transmissions can be formed. The writer has used sectors having openings varying from 1° to 230°.

N is a Siemens & Halske Precision volt-ammeter, Type 7K. It is equipped with an external adjustable shunt having the following steps: 0.424, 0.322, 0.254, 0.203 and 0.150 ohms. The internal resistance of the meter is 10 ohms and it requires 0.0045 ampere to produce a deflection of 150 scale-divisions. This ammeter with shunt was calibrated at 80, 100, 120 and 140 divisions for each shunt-step by using a standard resistance with a Leeds & Northrup potentiometer. Current values when the pointer is deflected 100 divisions are respectively 0.07319, 0.09623, 0.12033, 0.15044 and 0.20115 ampere.

The pyrometer lamp has a filament about 0.033 mm. in diameter and it requires a current of 0.2350 ampere to match in brightness a black-body at 1828°K. This current causes a deflection of 116.7 divisions when using the fifth shunt; it is the largest current that should be sent through this lamp, since lamps with tungsten filaments will not remain constant for any reasonable length of time if used to match bodies whose brightness-temperatures are greater than 1828°K. The lowest temperature that can conveniently be measured when using the colored glasses is about 1080°K but the curve can be extended down to 975°K by removing the glasses. The current required through the pyrometer lamp when a temperature of 975° is being measured is 0.0818 ampere. The values of the pyrometer-lamp currents given in this paragraph refer to the particular settings of the lens, lamp and telescope shown in figure 7. The aperture of A was U. S. 4 and the discs having apertures of 13 mm. and 15 mm. were used at 1828 and 975° respectively.

In series with pyrometer lamp is the storage battery *O*, the ammeter *N* and the two rheostats *P*. The rheostats are connected in parallel; one has a resistance of 40 ohms and the other a resistance of 107 ohms. A two-volt battery is sufficient when measuring the lower temperatures but a four-volt one is necessary for most of the range.

With the set-up shown in figure 7 the background is magnified about seven diameters. Very often such large magnification is not desirable. With the instrument here described, much smaller magnifications can be used if the lamp and lens are moved closer together. The telescope must then be placed at such a distance from the lamp that the filament may be seen distinctly. If the background is large it will be found very convenient to use a lamp having a filament larger than 0.033 mm.; one of twice this diameter is very commonly used in practice. For each setting of the lens, lamp and telescope, a calibration will be required.

Millimeter profile paper was used for plotting the calibration curves. For the ammeter curves the writer found that a scale of 0.0002 ampere per mm. for the current and 0.2 division per mm. for the deflection, gave current-deflection curves from which currents could be read with an error of less than 0.0001 ampere. The pyrometer-lamp current-temperature curves were drawn to a scale of 0.0002 ampere per mm. for the current and 2° per mm. for the temperature; this was sufficiently accurate for the needs of the writer. Degrees-correction plotted as a function of the observed brightness-temperature gave a useful curve because the observations were made through an absorbing medium. Since a large number of temperature determinations of the same substance were made, a curve connecting brightness-temperature and true-temperature saved much laborious calculation. The slope of the pyrometer-lamp curve changed from point to point. For the set-up of figure 7 it was such that, in the neighborhood of 1000°K, a change of one milliampere in the current through the lamp represented a change of 13° in the temperature of the background; at 1100° the variation was 9° per milliampere; at 1700° the rate of change was 3° per milliampere.

The writer in conclusion wishes to thank the Physics Department for placing at his command such good workshop facilities; Professor L. P. Sieg, under whose supervision the work was done, for his keen interest; Mr. J. B. Dempster for much valuable information regarding workshop methods; and Dr. A. G. Worthing of the Nela Research Laboratory for many valuable suggestions concerning optical pyrometry and for furnishing the calibrated standard-lamp and a pyrometer-lamp.

REFERENCES

(1) Worthing & Forsythe, Phy. Rev., 4, 163-176, 1914.
(2) Pyrometry (see note below), 293, 1920.
(3) Worthing, Phy. Rev., 10, 377-394, 1917.
(4) Hyde, Cady & Forsythe, Astrophy. Jour., 42, 294, 1915.
(5) Pyrometry, 319.
(6) Forsythe, Gen. Elect. Rev., 20, 749, 1917.
(7) Pyrometry, 306.

(8) Hyde, Cady & Forsythe, Phy. Rev., 10, 395, 1917.
(9) Hyde, Gen. Elect. Rev., 20, 819, 1917.
(10) Pyrometry, table on 337.
(11) Forsythe, Astrophy. Jour., 34, 353, 1911.
(12) Mendenhall & Forsythe, Phy. Rev., 4, 162, 1914.
(13) Pyrometry, 313.
(14) Pyrometry, 367-379.
(15) Coblentz, Sci. Pap. Bu. Stand. No. 406, Dec. 1920.
(16) Worthing, Astrophy. Jour., 36, 345, 1912.

"Pyrometry" is a volume containing "The Papers and Discussion of a Symposium on Pyrometry Held by the American Institute of Mining and Metallurgical Engineers at its Chicago Meeting, September, 1919, in co-operation with the National Research Council and the National Bureau of Standards." This 700-page book contains a wealth of information regarding temperature measurement.

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MEASUREMENTS OF THE AMPLITUDE OF VIBRATION OF THE DIAPHRAGM OF THE HEWLETT TONE GENERATOR

(*ABSTRACT*)

C. E. LANE

The "New Tone Generator"[1] designed by Dr. C. W. Hewlett promises to be a very valuable instrument for use as a precision source of sound. The operation of the instrument has been investigated mathematically by its designer[2] and a method is given for calculating the amplitude of vibration of its diaphragm from the electrical input. The writer herein describes a method whereby it has been possible to make actual measurements of the amplitude by mechanical means for comparison with the calculated amplitudes.

The tone generator was used in a vacuum tube oscillatory circuit from which the desired frequencies of alternating current were obtained.

For the purpose of making these measurements an electrical micrometer was constructed (Fig. 9). This micrometer operated

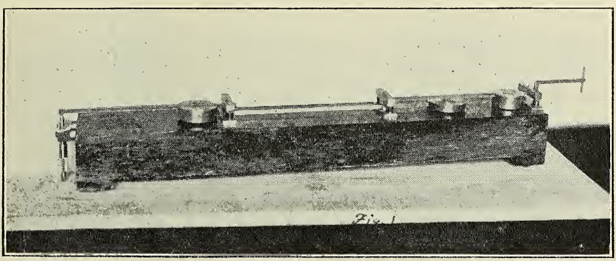


Fig. 9

on the same principle as the one described by P. E. Shaw in the Proceedings of the Royal Society, Vol. 76, page 350. The smallest divisions of this micrometric arrangement measured distances of 10.6 cm. and estimations could be made to tenths of a division.

[1] Physical Review, Vol. XVII, p. 257.

[2] Work not yet published.

Shaw used his instrument only for measuring the displacement of the diaphragm of a telephone receiver. In this work the instrument was used to measure the amplitude of vibration of the diaphragm when it was excited by an alternating current.

Measurements were not made directly on the tone generator because its position of equilibrium did not remain fixed. The amplitude of vibration of the diaphragm of an ordinary head receiver was measured and then by a method of comparison the desired measurements were obtained. From data on the receiver, curves were plotted which showed the relation between the amplitude of the receiver diaphragm and the current through it. Figure 10

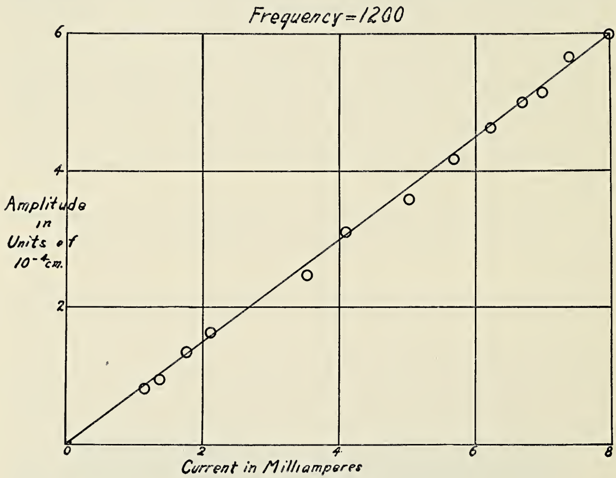


Fig. 10

shows one of the curves for a frequency of 1200 vibrations per second. All of the curves obtained were similar to this, showing an approximate linear relation between the current and the amplitude. In Table 1 below are some of the constants which when

TABLE I

Frequency	Constant (Amplitude for 1 Ampere)
1200	.075 cm.
1440	.0235 cm.
1600	.0175 cm.
2200	.0070 cm.
3700	.0412 cm.

multiplied by the current for the corresponding frequency give the amplitude. After these constants were once obtained it was only necessary to measure the current through the receiver in order to know its amplitude for any given frequency.

To make the comparison between the amplitude of the receiver and the tone generator the arrangement shown in figure 11 was

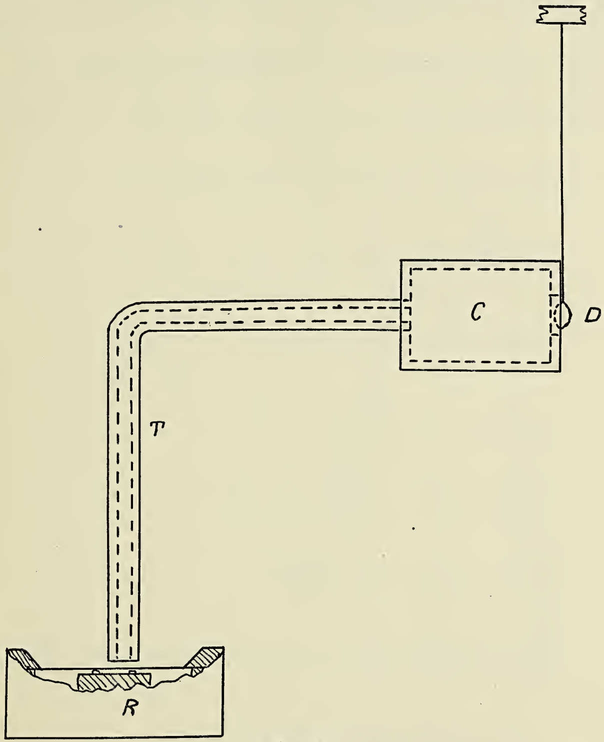


Fig. 11

used. R is the receiver, T is a tube leaving the resonating chamber C and terminating just above the receiver diaphragm, D is a Rayleigh disc mounted at an opening in the opposite end of the chamber from which the tube leaves. In this comparison it was assumed that if the diaphragm of the receiver thus arranged and vibrating with a given frequency and amplitude gave a certain de-

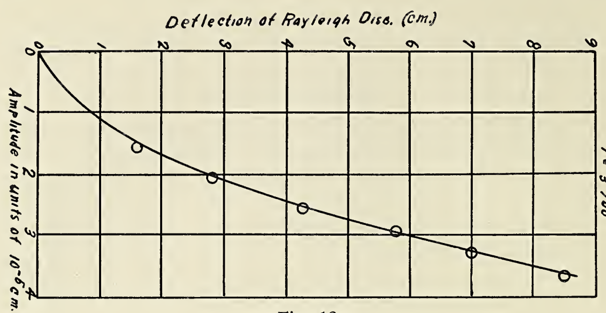
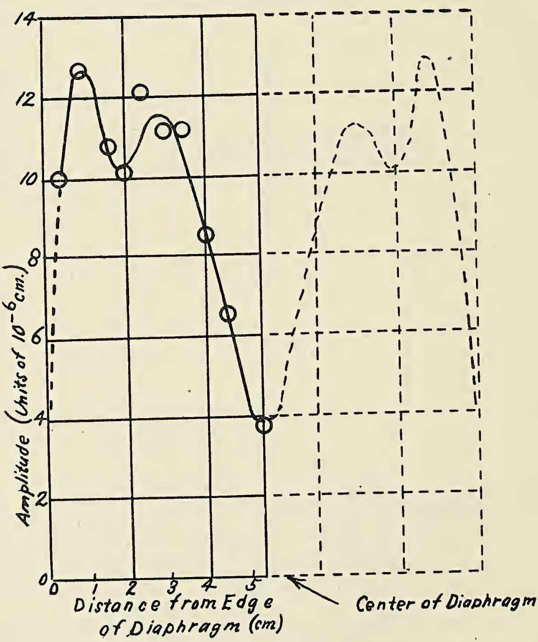


Fig. 12



Frequency = 2200

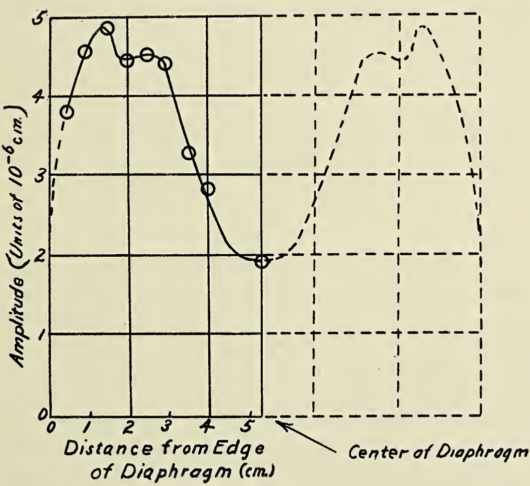
D.C. = 1.0 Ampere, A.C. = 0.1 Ampere

Mean Amplitude = 1.01×10^{-5} cm.

Fig. 13

flection of the Rayeigh disc, then any other membrane placed in the same position and vibrating with the same frequency that gave the same deflection would have the same amplitude. Thus it was possible by means of the receiver to calibrate the deflection of the Rayleigh disc in terms of the amplitude of the vibrating membrane under the tube. Calibration curves were obtained for four different frequencies. Figure 12 shows the one obtained for a frequency of 3700.

The amplitude of the diaphragm of the tone generator was determined by this means for frequencies of 1440, 1600, 2200, and 3700. These amplitudes were measured for larger values of current and then reduced to values for a direct current of 1.0 ampere and an alternating current of 0.1 ampere. The amplitude was not the same at different distances from the edge of the diaphragm. Figures 13 and 14 show the value of the amplitude for different positions on the diaphragm for frequencies of 2200 and 3700. The other two frequencies gave similar curves. The mean value of the amplitude was obtained by taking the



Frequency = 3700

D.C.= 1.0 Ampere, A.C.= 0.1 Ampere

Mean Amplitude = 4.32×10^{-6} cm.

Fig. 14

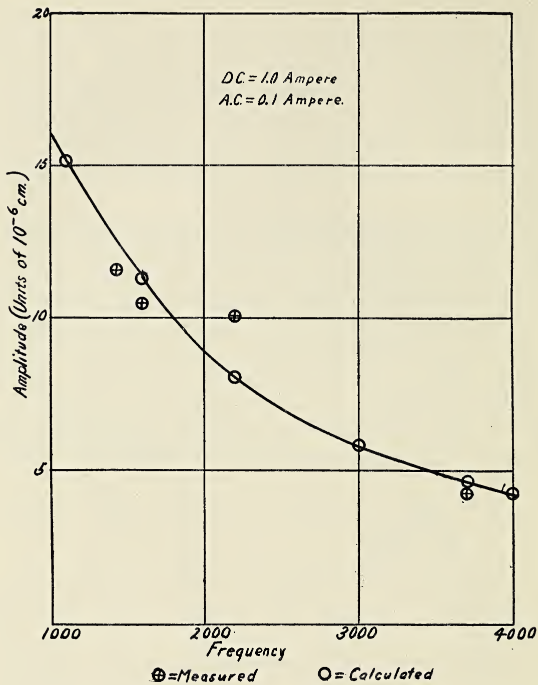


Fig. 15

root-mean-square of the amplitude over the instrument weighted with the area to which the different amplitudes corresponded. In figure 15 a curve is given which shows how near the measured amplitudes lie to the curve of the calculated amplitudes.

These measured values of amplitude agree as well as might be expected with the calculated values for the chance of experimental error in the method used is fairly great. In conclusion, it would seem that one is safe in assuming that the method for calculating the amplitude of vibration of the diaphragm of the tone generator as provided by Doctor Hewlett will give the true amplitude nearly enough for practical purposes.

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MEASUREMENTS OF THE MINIMUM AUDIBLE INTENSITY OF SOUND FOR TONES OF HIGH FREQUENCY

C. E. LANE

Many investigators have worked on the problem of determining the minimum amount of sound energy necessary for audible perception, but most of the investigations have been concerned with sounds of ordinary frequency and very little attempt has been made to make such a determination in absolute units near the upper limit of the range of audition. The mechanical difficulty of securing tones of sufficient intensity at these high frequencies is great, and, furthermore, it is not so easy to ascertain the amount of sound energy given out from the sounding apparatus at these values of frequency as at lower values.

In this investigation the Hewlett tone generator was used as a source of sound and the amount of sound energy given off was computed from the amplitude of vibration of the diaphragm of the instrument. (See preceding article.)

From the equations for sound waves derived in terms of displacement, it follows that the amplitude of the air wave near the diaphragm has the same value as the amplitude of the diaphragm and the total amount of sound energy passing out from the instrument is given by

$$4SdA^2\pi^2f^2V$$

where S is the area of each side of the diaphragm, d is the density of the air, A is the amplitude, f is the frequency, and V is the velocity of sound.

If the observer is stationed at a given distance from the sounding apparatus and the amplitude is reduced until he is just able to hear the tone, one could calculate from the amplitude the total amount of energy given off at this intensity, and, if the fractional part of this total energy flowing through a square centimeter at the observer is determined, the problem is solved. If the sound energy leaving the tone generator passed out with equal intensity in every direction it would only be necessary, in order to determine the flux of energy necessary for audition, to divide the total energy given off when the tone is just audible by the area of a sphere with a radius equal to the distance from the apparatus to the ear of the observer. However, since the sound does not pass out with equal intensity in every direction, this would only give the mean value of the flux of energy at that distance. In order to determine the actual value of E at the position of the observer (E being used to denote the number of ergs of sound energy flowing through a square centimeter per second for audition) one must multiply the mean value obtained by this method by some number R which gives the ratio of the intensity of the sound at the observer to the mean value of the flux taken over the whole sphere. Or one would have

$$E = \frac{4SdA^2\pi^2f^2V}{4\pi D^2} R$$

where D is the distance between the observer and the tone generator.

The values of R for the frequencies used were found by stationing the observer at a fixed distance from the tone generator and taking observations with different angles between the direction from him to the source of sound and the normal to the diaphragm of the instrument. The amplitude of the instrument was varied until the tone was just audible at each of these positions. It was assumed that if E_x represented the total amount of sound

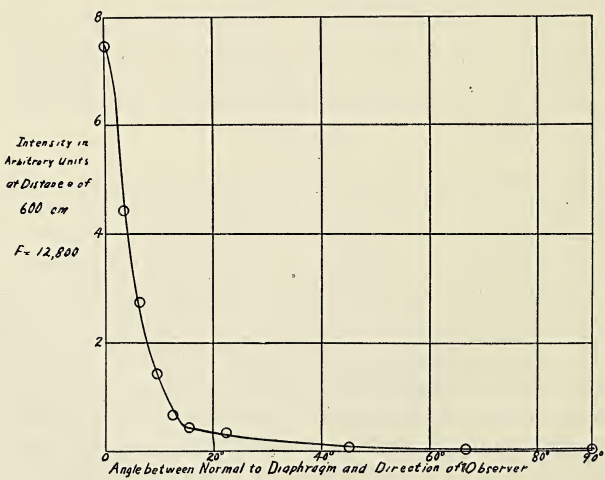

Fig. 16

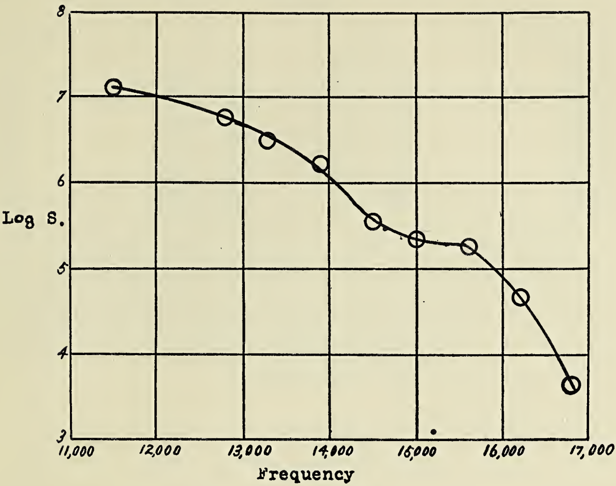

Fig. 17

energy required to be given out from the source for audition with the direction of the observer making any angle x with the normal, E_x having different values at different angles; or in other words, if E_x represented the different intensities at the source required to produce equal intensities at a constant distance but with different values for x, that the ratio of the intensity of sound passing out in different directions as given by x, when the energy leaving the source had a constant value E_c were proportional to $1/E_x$. Figure 16 gives the intensity flux in different directions from the diaphragm as determined by this method. The intensity, in arbitrary units, is plotted as the ordinate, and the angle x as the abscissa. These results were obtained for a frequency of 12,800. The value of D was 600 cm. From the curve, R, for the direction of the observer normal to the diaphragm, was found to be about 50, and the value for E obtained was $.65 \times 10^{-7}$ ergs. By this method the value of E was found for several other frequencies and the results are given in Table 1. The column headed S in this table gives the sensitivity of the ear for the different frequencies where S is defined as 1/E. Figure 17 shows graphically the change in sensitivity of the ear with frequency. In order that it all might be shown on the same curve log S is plotted instead of S.

TABLE I

Frequency	E (ergs)	S	Log S
11,500	$.65 \times 10^{-7}$	1.54×10^{7}	7.19
12,800	1.66×10^{-7}	6.00×10^{6}	6.78
13,300	3.14×10^{-7}	3.17×10^{6}	6.50
13,900	5.66×10^{-7}	1.77×10^{6}	6.25
14,500	2.77×10^{-6}	3.61×10^{5}	5.56
15,000	3.60×10^{-6}	2.38×10^{5}	5.38
15,700	5.80×10^{-6}	1.72×10^{5}	5.23
16,200	2.05×10^{-5}	4.87×10^{4}	4.69
16,800	2.00×10^{-4}	5.00×10^{3}	3.70

These results, while only for one observer, are significant. They show that near the upper limit of audition the sensitivity of the ear falls off very rapidly for an increase in frequency beyond a certain limit. It was not found possible to produce sound of sufficient intensity at a frequency of 17,000 for audition for the observer from whom these results were obtained.

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A SINGLE BAND ACOUSTIC WAVE FILTER

G. W. STEWART

(*ABSTRACT*)

Theoretical considerations lead to the conclusion that a single band acoustic wave filter can be made in a manner analagous to the electric wave filter and also that in the acoustic case there should be a repetition of the band at high frequencies. The ac-

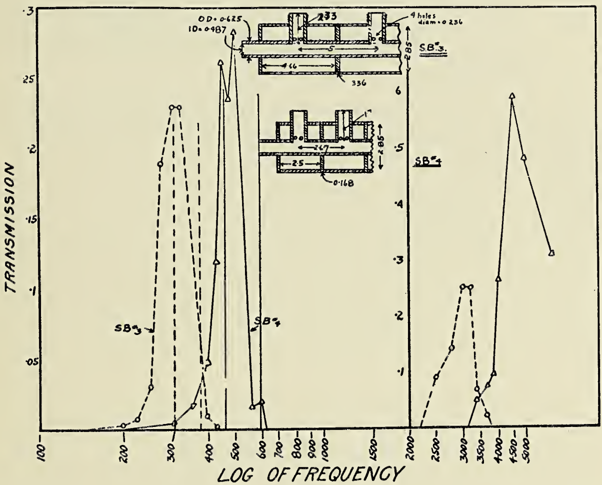

Fig. 18

companying drawing (Fig. 18) shows the results of experiments with two filters whose dimensions also are indicated.

The transmission band is computed from the following formula giving the limiting frequencies:

$$(2\pi f_1)^2 = a^2 \left(\frac{S_2}{l_2 V_2}\right)$$

$$(2\pi f_2)^2 = a^2 \left(\frac{S_2 l_1 + S_1 l_2}{l_1 V_2 l_2}\right)$$

wherein f_1 and f_2 are the computed limits of the band, S_2 is the area of the side tubes. S_1 is the area of the conducting tube.

l_1 is the length between openings of the side tubes.
l_2 is the length of the side tubes.
V_2 is the volume of the chamber surrounding each side tube.
a is the velocity of sound.

The computed frequencies are shown by vertical lines, one pair for each filter.

Each filter consists of three cells.

It is found theoretically that f_1 corresponds to the resonance frequency of the volume V_2 and neck l_2 and also experimentally that:

(1) The peaks correspond to f_1 closely.
(2) The cut off frequency corresponds to f_2 closely.
(3) Filtering action from f_2 to a frequency almost ten times as great is very good, the transmission being less than one-millionth part.

It is supposed that the band at the higher frequency is caused by the fact that, as in a Helmholtz resonator, the resonating frequency has more than one value.

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THE EFFECT OF DRAWING ON THE CRYSTAL STRUCTURE OF TUNGSTEN WIRES.

L. P. SIEG

The writer has in various places published results of tests on the coefficient of rigidity of drawn tungsten wires. The latest [1] results indicated clearly that in a series of wires drawn down from the same original stock the coefficient of simple rigidity progressively increased as the diameters of the wires decreased. For example, the value of "n" ranged in the case of two extremes of five such wires from 14.15×10^{11} to 15.10×10^{11} dynes per square cm., for corresponding radii of 0.0227 cm., and 0.00240 cm. The hypothesis was put forth at that time that a change in the crystal structure which was limited to the surface, and which yielded a greater rigidity for the wire would account for the results. This, because as the wires become progressively smaller the effect of the surface would become more and more pronounced.

No opportunity came for testing this suggestion until after the war. Last year the five wires were again tested for their rigidities, the results from which tests have not yet been reported. However, the tests agreed excellently with those taken two years previously, establishing incidentally that the changes were very likely permanent.

The examination involved a photomicrographic study of sections of the wires. To accomplish this short lengths of wires were embedded in two copper plates by squeezing together the plates, with the wires between them, exerting great enough pressure to mould the copper around the wires. The copper plates were then dressed down, first roughly with a file (which failed to make much impression on the tungsten), then with successively finer grades of carborundum paper. The last stage of the polishing was done with rouge. Great patience and care is required throughout all this operation, greater even than for most metals on account of the extreme hardness of the tungsten. One must have the patience not to progress to a finer grade of the abrasive until he is sure that all scratches of a size larger than the grade he is using have been obliterated. After the polishing was completed the surfaces were

[1] Ia. Acad. Science, Proc. 24, p. 207, 1917.

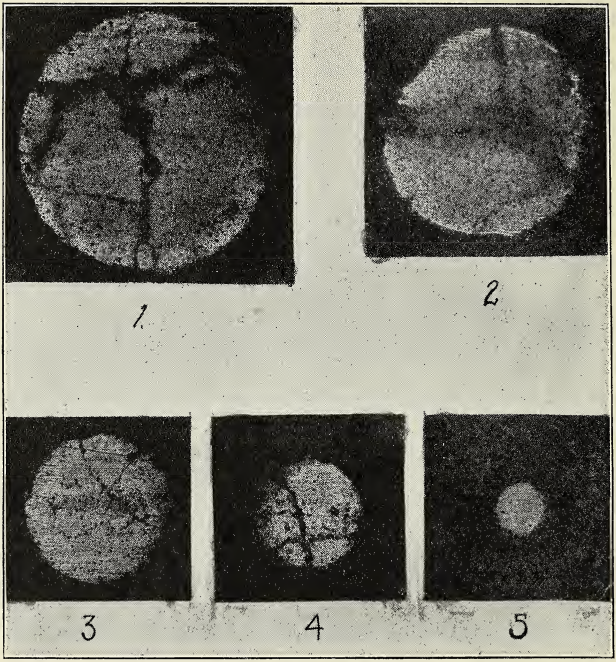

Fig. 19. Photomicrographic sections of five tungsten wires, drawn down successively from the same original wire.

complete blanks, so it was, as usual, necessary to etch the surfaces. The most successful liquid was boiling hot hydrogen dioxide. A mixture of hydrofluoric and nitric acids served nearly as well.

The accompanying photomicrographs (See Fig. 19) taken with monochromatic green light show, probably as well as any reproduction can, the effect sought. However, it must be said that even the original negatives failed to show with anywhere the clearness the structure which one could observe directly through the eyepiece. In the present half tone the magnification is 110 diameters. The actual sizes of the wires were respectively, 0.0227, 0.01762, 0.01262, 0.00784, and 0.00240 cm., and the corresponding sections are shown in numbers 1 to 5 in the accompanying figure. The cracks shown in the wires developed during the process of embedding the wires in the copper, but these do not do any damage as far as the present tests are concerned. The photographs show that the crystal structure near the surface is distinctly different from that throughout the body of the crystal. In No. 1 the lighter-colored rim, free from crystals (or apparently so) is clearly in evidence. In No. 2 the same ring appears, and it is practically of the same depth as that in No. 1. In No. 3 the light area has penetrated much farther, the dense crystals being very much less in evidence. In No. 4 the dark crystals are to be seen only in isolated spots, while in No. 5 the dark grains are totally absent. This effect can not be attributed to variations in polishing and in etching, for throughout the wires were treated exactly alike in order to avoid that contingency.

Exactly what the difference is between the two phases of crystal structure, the writer is not in a position to state. He is of the opinion, however, that the light-colored areas represent the fact that the amorphous cement is much in excess, and that the crystals in that region are so fine as to be beyond the resolving power of the microscope. According to modern theories of such crystals, the amorphous state should exhibit the higher elasticity.

In conclusion, whatever the structures of the two crystal states may be, it has been demonstrated that drawing has an effect on the surface which is different from the effect deeper in the structure of the wires. This accounts for the progressive changes in the elastic constants of the wires.

State University of Iowa.

A NOTE ON KATER'S REVERSIBLE PENDULUM

L. P. SIEG

In one of our laboratory classes recently, in connection with a routine experiment with Kater's pendulum, certain of the students were confronted with the situation in which, although the periods of vibration from each of the two knife edges were practically identical, the distance between the knife edges was by no means equal to the length of the equivalent simple pendulum. None of the treatises on dynamics available offered any help in their difficulty. In all the discussions it was virtually stated that when the periods from the two knife edges were equal the distance between knife edges was equal to the length of the simple pendulum of equal period.

When their difficulty was presented to the present writer he was at once reminded of a study he had made some twenty years ago, but which at that time he had deemed unimportant enough for publication. In this study, a paper read before a Sigma Xi meeting, the writer pointed out that the shifting of a knife edge on any compound pendulum causes a variation in the period in which in certain cases it can pass through a minimum. In other words there are two positions of a knife edge with respect to the center of gravity of the system in which the periods of vibration will be the same. Some time later an article by Tatnall [1] appeared and covered almost identically the same ground. As neither of these treatments specifically deals with the present case it is thought worth while to publish a note on the question.

In Fig. 20-A, let C denote the center of gravity (in future abbreviated to c.g.) of the system, and O_1 and O_2 the two points of suspension. Further let h_1 and h_2 be respectively the distances of the c.g. of the whole system from O_1 and O_2, and let T_1 and T_2 be respectively the corresponding periods of vibration. Then we have the well-known expressions,

$$T_1 = 2\pi\sqrt{\frac{I}{M g h_1}} = 2\pi\sqrt{\frac{K^2 + h_1^2}{g h_1}} \quad \text{(1)}$$

$$T_2 = 2\pi\sqrt{\frac{K^2 + h_2^2}{g h_2}} \quad \text{(2)}$$

1 R. R. Tatnall, Phys. Rev., 17, p. 460, 1903.

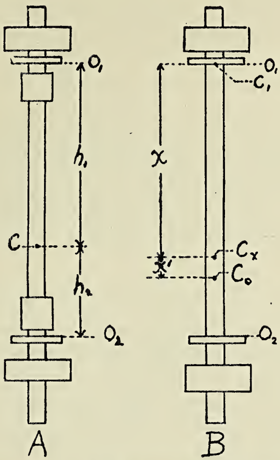

Fig. 20. Kater's pendulum. A, with weightless knife edges; B, with actual knife edges.

where I denotes the moment of inertia of the system about C, M is the total mass, g the acceleration of gravity, and K the radius of gyration of the system about C. Denoting by L_1 and L_2, respectively the lengths of the equivalent simple pendulums in the two cases, we have

$$L_1 = \frac{K^2 + h_1^2}{h_1} \qquad (3)$$

$$L_2 = \frac{K^2 + h_2^2}{h_2} \qquad (4)$$

Let us first, to avoid confusion, make the assumption that the knife edges have no mass, so that their movement will not affect the location of the center of gravity of the system. Later this assumption will be avoided. Let O_1 be at such a distance, x, from C that we have again the same length of the equivalent simple pendulum. Then from (3),

$$\frac{K^2 + h_1^2}{h_1} = \frac{K^2 + x^2}{x}$$

Solving for x, we have the two values

$$x = h_1 \qquad x = \frac{K^2}{h_1} \qquad (5)$$

Thus the knife edge O_1 can be either at a distance h_1 from C, as in the figure, or $\frac{K^2}{h_1}$ from C, and we shall have in both cases the same period of vibration. Similarly, from the other point of suspension, O_2, if y is the distance of O_2 from C we have two other equal periods of vibration if $y = h_2$, or $\frac{K^2}{h_2}$.

We can imagine then that our pendulum (Fig. 20-A) has four weightless knife edges, two on each side of the center, so adjusted with respect to the masses on the pendulum rod that when it is hung in turn from the four, the periods will be the same. The possible distances between knife edges, $x + y$, will then be seen to be,

$$h_1 + h_2,\ h_1 + \frac{K^2}{h_2},\ \frac{K^2}{h_1} + h_2, \text{ and } K^2 \left[\frac{I}{h_1} + \frac{I}{h_2}\right]$$

In general these four distances will be different, and only one of them corresponds to the length of the equivalent simple pendulum. In practice there is no difficulty, for one can by rough calculation determine if the knife edges are in the proper positions. Again, the laboratory forms of Kater's pendulum are usually so constructed that one can not easily attain on the actual pendulum the wrong positions of the knife edges, but in the case referred to in this article, the students had succeeded in doing just this thing.

It is evident that if there are two values, x, of the distances from O_1 to C that yield the same period of vibration, there must be some x beween them which is the only distance corresponding to a single period, and that a maximum or a minimum. Our function of x to be studied is $\frac{K^2 + x^2}{x}$, and a simple examination shows that this becomes a minimum for $x = \pm K$. Only the plus value of K need be considered, since the other value relates to the other support. The relation becomes more understandable on platting a typical curve connecting x and T. We have

$$T = 2\pi\sqrt{\frac{K^2 + x^2}{g x}} \quad \dots\dots\dots\dots (6)$$

or

$$T^2 = c\left[\frac{K^2 + x^2}{x}\right] \quad \dots\dots\dots\dots (7)$$

where C is a constant. In figure 21 we have such a graph for the special case where $C = 1$, and $K = 2$ (not supposed at all to represent the facts, but merely to represent the nature of the function). On the curve the point D represents the minimum. It is the only value of x corresponding to the period represented by the ordinate at that point. From A we draw the line ABC parallel to the X-axis. The two intersections B and C represent the two

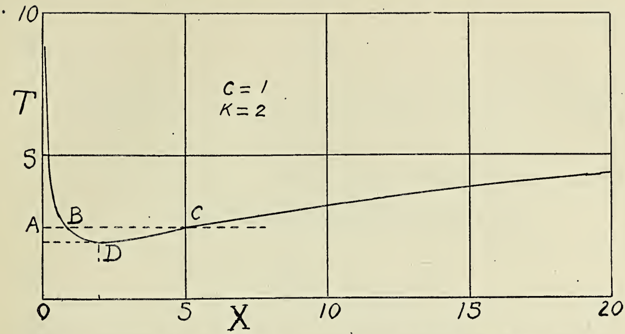

Fig. 21. Variation of the period of vibration, I, with the distance, x, from knife edge to center of gravity of the whole pendulum.

values of x corresponding to the period A. To revert for a moment to the first paragraph of this article, my students had chanced in their experiment on the distance AB, when they should have employed the greater distance AC for h_1.

Let us assume now that the knife edges have mass, and let us refer to Fig. 20-B. We can assume, without any loss of generality, that we can attain equality of periods by moving solely O_1. Hence the mass of O_2 can be considered as merged with the remainder of the pendulum mass.

Let M = the mass of all the pendulum excepting O_1.
m = the mass of O_1.
C_x = the center of mass of the whole.
C_0 = the center of mass of M.
C_1 = the center of mass of m_1 (assume C_1 to be coincident with the near edge of O_1. The error will be only a small constant correction).
x = the distance of O_1 from C_x.

Then we have

$$T_1 = 2\pi\sqrt{\frac{I}{(M+m)g\,x}} = 2\pi\sqrt{\frac{(M+m)\,K^2+(M+m)x^2}{(M+m)g\,x}}$$

$$= 2\pi\sqrt{\frac{K^2+x^2}{g\,x}} \qquad (8)$$

where K is the radius of gyration about C_x, and I is the moment of inertia about O_1.

The only difference between equations (8) and (6) is that in the former K is not a constant, but is a function of x. Now let $C_0C_x = x'$, then

$$mx = Mx' \qquad (9)$$

and

$$x' = \frac{mx}{M} \quad \text{.............................} (10)$$

Let K_o be the radius of gyration of M about C_o, and k_o that of m about O_1. Then the moment of inertia about C_x is given by

$$I_o = (M + m)k^2 = Mk_o^2 + Mx'^2 + mk_o^2 + mx^2 \text{......} (11)$$

Substituting for x' from (10) we have

$$K^2 = \frac{MK_o^2 + mk_o^2 + m^2x^2/M + mx^2}{M + m} \quad \text{.............} (12)$$

Let

$$M = aM \text{.........................} (13)$$

then

$$K^2 = \frac{K_o^2 + ak_o^2}{1 + a} + ax^2 \text{......................} (14)$$

or

$$K^2 = B + ax^2 \text{.....................} (15)$$

where

$$B = \frac{K_o^2 + ak_o^2}{1 + a} \quad \text{........................} (16)$$

Substituting (15) in (8) we have

$$T_1 = 2\pi \sqrt{\frac{B + ax^2 + x^2}{gx}} = 2\pi \sqrt{\frac{B + (1 + a)x^2}{gx}} \text{.........} (17)$$

Again for every value of T_1 there are two values for x, except at the minimum point. Determining from (17) the value of x to make T_1 a minimum, we find

$$x = \sqrt{\frac{B}{1 + a}}$$

This readily reduces to the former value $x = K$, if $m = O$ (and hence $a = O$).

The form of (17) is seen to be the same as that of (1), and so here too we have the possibility in the most general case of four positions of the knife edges which would yield the same period of vibration.

In conclusion then we can state the following: The equality of periods, when a pendulum is suspended in turn from two knife edges, is a necessary condition that the length between the knife edges may be equal to the equivalent simple pendulum, but it can not be said to be a sufficient condition.

State University Of Iowa.

THE COEFFICIENT OF SIMPLE RIGIDITY AND YOUNG'S MODULUS FOR HEXAGONAL CRYSTALS OF SELENIUM

L. P. SIEG and R. F. MILLER

Elastic constants determined from drawn wires are of considerable practical use, but they are not very illuminating on the subject of the structure of matter. A drawn wire is a heterogeneous mass of matter in crystalline and amorphous states, with never any regularity in composition or of crystalline structure. In fact the elastic constants so determined are not so much characteristic of the substance, say copper, as of the particular physical state of that substance. If, however, one could employ an isolated crystal of a simple elementary substance, he ought to be able to determine the elastic constants of the substance itself, rather than that of its particular physical state.

This thought has been in mind for some time, in fact ever since the laboratory has had so liberal a supply of large selenium crystals which were made by Dr. F. C. Brown, of the Bureau of Standards. Last summer (1920) we undertook the determination of the simple rigidity and of Young's modulus for some of these crystals, and the following account records the results of these first experiments.

In figure 22 we have a photograph of some typical crystals with which we worked. The length of one cm. is indicated on the photograph, so that the actual sizes of the crystals can be estimated There were available many larger crystals, but careful selection indicated that the smaller ones were more regular. The ideal form of these crystals is that of slender regular haxagonal prisms, but actually they proved to vary from this in two respects: the forms were really those of truncated prisms, and the sections, while hexagonal, were not regular. The angles, as is generally true in crystals were practically perfect, in this case 120°, but the sides varied in length. These two irregularities were fortunately slight, for otherwise anything like accuracy in determining the elastic constants would be out of the question.

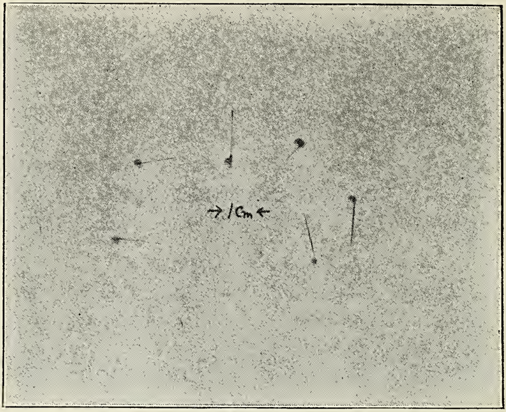

Fig. 22. Types of selenium crystals used in the determination of their elastic constants.

I. YOUNG'S MODULUS

For the determination of Young's modulus, the method of bending was used. The crystal studied was carefully measured, then laid on two parallel knife edges at a known distance apart, and the bend at the middle, for various loads, was recorded. The bends were observed with a traveling microscope. In fact everything proceeded as in an ordinary laboratory experiment for this determination, excepting that everything was on a smaller scale, and correspondingly smaller distances had to be measured. A schematic drawing of the arrangement of crystals and apparatus is shown in figure 23. The microscope M_1 was used to measure the

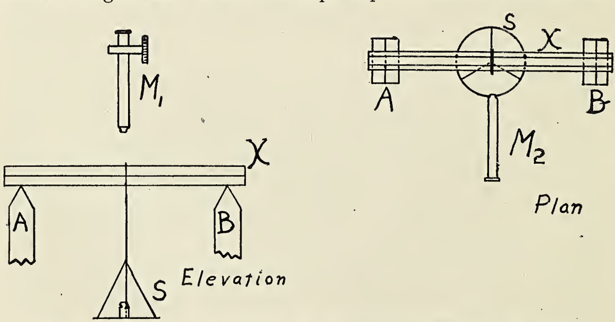

Fig. 23. Arrangement of apparatus for determining the bending of crystals.

distance between the knife edges, and the centering of the point of application of the bending force. M_2 was employed to measure the bend. A and B are the knife edges, S the scale pan, and X the crystal. The face widths were measured previously to the experiment by attaching the crystals with wax along the axis of a rod, which could be rotated so as to present in succession the six faces. Considering only one crystal, No. 6 in detail, as typical of all the others, we have in figure 24, drawn to scale, the sections of the

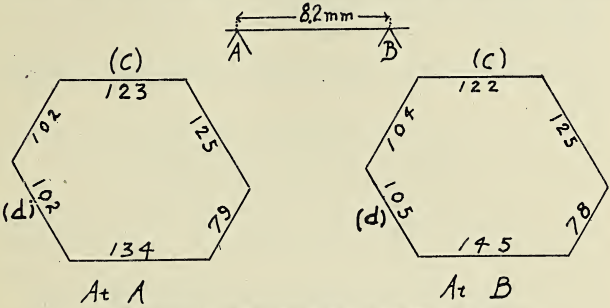

Fig. 24. Sections of a typical crystal at the two knife edges.

crystal at the two knife point edges, A and B. The numbers on the edges of the crystals are in micra. The detailed results for this crystal are given in Table I.

TABLE I

Face C above. Crystal No. 6

Load (mg)	Reading (adding load) (mm)	Bend (mm)	Reading (Subtracting load) (mm)	Bend (mm)
pan	.423		.288	
400	.409	.014	.277	.011
800	.398	.011	.264	.013
1200	.385	.013	.250	.014
pan	.425		.290	
400	.411	.014	.277	.013
800	.398	.013	.264	.013
1200	.387	.011	252	.012
1600	.376	.011	.240	.012
pan	.494		.357	
400	.483	.011	.345	.012
800	.470	.013	.332	.013
1200	.457	.013	.322	.010
pan	.493		.356	
400	.482	.011	.345	.011
800	.469	.013	.334	.011
1200	.457	.112	.322	.012
1600	.446	.011	.312	.010

pan	.426		.293	
400	.415	.011	.281	.012
800	.404	.011	.269	.012
1200	.391	.013	.256	.013
1600	.380	.011	.243	.013
pan	.431		.296	
400	.419	.012	.285	.011
800	.407	.012	.271	.014
1200	.395	.012	.259	.012
1600	.383	.012	.247	.012

Mean bend for 400 mg = 0.0121 mm
Mean bend for 1 gram = 0.0303 mm
Mass of pan............ = 51 mg

A summary of all the results for the crystals tested is given in Table II.

TABLE II

Summary of results for all crystals

Separation of knife edges, 8.2 mm

Crystal	Face dimensions, in micra, taken clockwise (as in Fig. 24), first face at top		Bend per gram (mm)
	At A	At B	
2	121, 77, 114, 115, 81, 103	136, 120, 127, 144, 119, 136	.0315
2	103, 121, 77, 114, 115, 81	136, 136, 120, 127, 144, 119	.0322
2	81, 103, 121, 77, 114, 115	119, 136, 136, 120, 127, 144	.0231
5	94, 36, 54, 79, 40, 40	109, 20, 74, 83, 47, 42	.4875
6	123, 125, 79, 134, 102, 102	122, 125, 78, 145, 105, 104	.0303
6	102, 102, 123, 125, 79, 134	105, 104, 122, 125, 78, 145	.0231
8	41, 48, 47, 38, 58, 48	62, 66, 77, 40, 85, 53	.3167
9	82, 73, 74, 78, 66, 58	95, 82, 76, 81, 91, 61	.0890
9	78, 66, 58, 82, 73, 74	81, 91, 61, 95, 82, 76	.0880
9	58, 82, 73, 74, 78, 66	61, 95, 82, 76, 81, 91	0710

If the crystals had been regular hexagonal prisms one could easily have arrived at a value for Young's modulus by applying the formula

$$Y = \frac{W L^3}{48\, d\, M} \quad \text{........................(1)}$$

where Y is Young's modulus, W the load in dynes, L the length between knife edges in cm, and M the moment of inertia (really moment of area, for the mass does not enter) of the section about the horizontal axis determined by the intersection of the neutral plane with the cross section of the crystal. Inasmuch as the crystals were not uniform, the exact formula for Y would be well nigh impossible of derivation. However, one can use the following method of approximation with a fair accuracy. In figure 25 a sketch of a crystal face is given, with a great exaggertion in the differences in the two edges, a_1 and a_2. The former is an edge of the section at the knife edge A, and the latter at B. For any

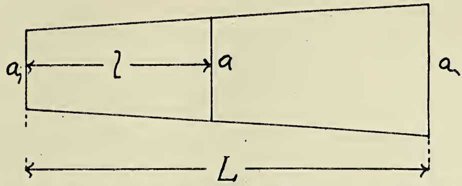

Fig. 25. Sketch of one face of the truncated hexagonal prism.

cross-section, taken at a, distant l from a_1, the expression for M is $\frac{5a^4\sqrt{3}}{16}$, if we suppose the section to be a regular hexagon. Assuming this, as a rough approximation, and using the mean of the six edges as a_1 and a_2, respectively, we can obtain the mean value of M for the section whose edge length is a, by the following method.

$$a = a_1 + (a_2 - a_1)\frac{l}{L} \quad \dots\dots (2)$$

Let

$$a_1 = c,\ a_2 - a_1 = e \quad \dots\dots (3)$$

then

$$a = c + \frac{e\,l}{L} \quad \dots\dots (4)$$

and

$$M\,l = \frac{5\sqrt{3}}{16}\left[c + \frac{e\,l}{L}\right]^4 \quad \dots\dots (5)$$

where M_l is the moment of area at the distance l from a_1. Now if M is the mean moment of area for all sections of the frustum,

$$\overline{M}\,L = \frac{5\sqrt{3}}{16}\int_0^L \left[c + \frac{e\,l}{L}\right]^4 d\,l \quad \dots\dots (6)$$

or, integrating, and substituting the limits,

$$\overline{M} = \frac{5\sqrt{3}}{16}\left[c^4 + 2\,c^3e + 2\,c^2e^2 + c\,e^3 + e^4/5\right] \quad \dots\dots (7)$$

Employing the value of $\overline{M}$ from (7) for M in (1), we have an expression for the value of Young's modulus. Applying these two equations specifically to crystal No. 2, first case (Table II), we have

$a_1 = .0102$ cm (mean of six edges)
$a_2 = .0130$ cm (mean of six edges)
$c = .0102$ cm
$e = .0028$ cm

Substituting in (7), $M = 1.008 \times 10^{-8}$ cm^4 (area $\times$ distance^2).

Thence substituting in (1), where

$$W = 980 \text{ dynes}$$
$$L = 0.82 \text{ cm}$$
$$d = 0.00315 \text{ cm}$$
$$M = 1.008 \times 10^{-8} \text{ cm}^4$$
$$Y = 3.57 \times 10^{11} \text{ dynes per cm}^2.$$

The results for all the crystals, employing this same method, are given in Table III. While the range in values for Young's

TABLE III

Crystal	Young's Modulus $\times 10^{-11}$ (c. g. s.)
2	3.57
2	3.49
2	4.86
5	3.28
6	4.34
6	5.70
8	6.60
9	6.77
9	6.85
9	8.49
	Mean 5.40 ± 0.4

modulus is large (the probable error being about 7 per cent of the mean), it is not so large as the range in values found from tables of results for common substances in the form of drawn wires. It must be remembered that in expressions (7) and (1) it has been assumed that the mean of the six sides of the hexagon at the two knife edges, which are the numbers employed for a_1 and a_2, are really the proper numbers to use. Since the hexagons are not regular, it is not correct to use the mean, but no other simple method seemed available. What one really wants is the side of the regular hexagon which possesses the same moment of area as the given irregular hexagon. An attempt was made to draw to scale some of the sections, and to obtain the moments of area by calculating each part separately, but the results as far as obtained did not differ very much from the present ones, and so the labor involved seemed unjustifiable. The mean value for Y indicates an elasticity roughly about one-third that of steel.

II. COEFFICIENT OF SIMPLE RIGIDITY

The experimental determination of the simple rigidity involved even more experimental difficulties than those encountered in the determination of Young's modulus. The method of vibration of a torsion pendulum, using the crystal as the support, was employed. From a knowledge of the period of vibration, the moment of area of a section of the crystal about an axis perpendicular to the section at its center, the length of the crystal, and the moment of inertia of the vibrating body, the coefficient of rigidity can be calculated. The torsion of a rod of any but a circular section creates a very complicated condition, because not only is shearing of each section present, but also there is a complicated warping of each section. Indeed, this is the celebrated problem of De Saint-Venant.[2] However, it can be shown [3] that for a slender rod of any regular section, the torsional couple for a given angle of twist, θ, is given with sufficient accuracy by

$$\mathcal{T} = \frac{\omega^4 n \theta}{40 I L} \quad \text{(8)}$$

where $\mathcal{T}$ is the torsional couple, ω the area of cross-section, n the coefficient of simple rigidity, I the moment of area of the section about an axis through its center, and perpendicular to its plane, and L the length of the twisted crystal. For unit twist we have, letting $\theta = 1$ in (8)

$$\mathcal{T}_1 = \frac{\omega^4 n}{40 I L} \quad \text{(9)}$$

For a torsion pendulum we have

$$T = 2\pi \sqrt{\frac{I_0}{\mathcal{T}_1}} \quad \text{(10)}$$

where T is the period of vibration, I_0 the moment of inertia of the suspended mass, and $\mathcal{T}_1$ the torsional couple for unit twist. Equating the values of $\mathcal{T}_1$ from (9) and (10), we have

$$n = \frac{160 \pi^2 I_0 I L}{\omega^4 T^2} \quad \text{(11)}$$

or, as in the preceding case (section I) the moment of area is not constant from section to section over the length L, we can write (11)

$$n = \frac{160 \pi^2 I_0 L}{T^2} \left[\frac{I}{\omega^4} \right] \quad \text{(12)}$$

where the quantity in brackets refers to the mean value of $\frac{I}{\omega^4}$ over the length L. To find this we proceed somewhat as before. Let P be this mean value. Then

$$PL = \int_0^L \frac{I}{\omega^4}\, dl \quad \text{(13)}$$

2 Comptes Rendus 88, pp. 142-147, 1879.

3 Love, Treatise on the Theory of Elasticity: Vol. 1, p. 171, Camb. Univ. Press, 1892.

For a regular hexagon, $I = \frac{5\sqrt{3}}{8} a^4$, and $\omega = \frac{3}{2} a^2 \sqrt{3}$, in terms of the length of side, a. Then $\frac{I}{\omega^4} = .0237\ a^{-4}$. Using the same notation as in the first section,

$$a = c + \frac{e\,l}{L}$$

therefore

$$\frac{I}{\omega^4} = .0237 \left[c + \frac{e\,l}{L}\right]^{-4}$$

and (13) becomes

$$\bar{P} = \frac{.0237}{L} \int_0^L \left[c + \frac{e\,l}{L}\right]^{-4} d\,l = \frac{.0079}{e} \left[\frac{1}{C^3} - \frac{1}{(c+e)^3}\right] \ldots\ldots (14)$$

Finally we have the expression for n, by combining (12) and (14)

$$n = \frac{160\,\pi^2 I_0 L}{T^2} \left[\frac{.0079}{e}\right] \left[\frac{1}{C^3} - \frac{1}{(C+e)^3}\right] \ldots\ldots\ldots\ldots (15)$$

Four crystals were used in this determination, the data and results for which are given in Table IV.

TABLE IV

Crystal	Sides, in micra, taken in order — Small End	Sides, in micra, taken in order — Large End
2	121, 77, 114, 115, 81, 103	141, 134, 131, 154, 132, 147
3	128, 142, 123, 115, 144, 105	164, 186, 146, 167, 173, 132
11	65, 29, 62, 67, 24, 69	84, 43, 78, 77, 42, 74
12	81, 76, 35, 87, 78, 44	93, 128, 73, 115, 111, 99

Crystal	c(cm)	e(cm)	L(cm)	T(sec)	$n \times 10^{-11}$
2	.0102	.0038	0.98	6.37	0.664
3	.0126	.0035	1.66	7.285	0.421
11	.00527	.00136	0.92	23.46	0.756
12	.00669	.0036	1.28	14.40	0.750
					Mean 0.65 ± .05

The variation in n is about of the order of the variation in Y. Comparing results we have for the mean value of Y, 5.40×10^{11}, and for n, 0.65×10^{11} dynes per cm². Their ratio, Y/n is equal to 8.3. This is unusually large, at least compared to isotropic substances in which this ratio for common metals averages about 2.6. However, we are here dealing with a crystalline substance, not an isotropic one, and comparisons with the latter substances are of little value.

It has been shown in crystal theory that to determine completely the elastic constants of an hexagonal crystal would require the determination of five constants. This is a big reduction from the twenty-one constants required for the triclinic form of crystal. Voigt [4] has shown how one can determine these five constants, but to do so requires that one have sections of the crystal cut transversely to the principal axis, and at 45° to the axis, as well as the sections possessed in the present work. Voigt actually determined these five constants for quartz and for beryl. Such sections, with the crystals discussed here, are out of the question, and so one must content himself with the gross constants, such as those which we have here reported upon.

A few determinations of the logarithmic decrement led to remarkable constancy for results. For example, in crystals Nos. 3 and 12, which were quite different in size, the logarithmic decrement proved to be respectively 1.08 and 1.07. In these tests errors of measurement of the sides, or errors of assuming the sides equal do not enter, and these results go towards bearing out our belief that if we could obtain regular crystals, the elastic constants, experimentally determined, would show the same uniformity.

State University of Iowa.

[4] Voigt, Ann. d. Phys., 16, 398, 1882; 29, 604, 1886; 31, 474, 1887.

THE ABSORPTION OF LIGHT PASSING THROUGH DEEP SLITS AS A FUNCTION OF THE LENGTH AND DEPTH OF THE SLITS AND OF THE WAVE LENGTH OF THE LIGHT

(*Abstract*)

L. P. SIEG AND A. T. FANT

As indicated by Rayleigh, [1] practically every slit is a "Deep" slit, and a "Thin" slit can be obtained only with the greatest difficulty. Rayleigh used for the latter a fine scratch in a thin silver film deposited upon glass. In the present work [2] experiments were made with a series of slits with steel jaws, varying in depth from that of the thin safety razor blades to approximately 2.5 cm. The intensity of the transmitted light was experimentally determined as a function of the width and depth of the slits, and of the wave length of the light. For narrow slits, the narrowness depending upon the depth and wave length, practically complete polarization, with the electric vector parallel to the length of the slit, was noted, but exact measurements were deferred to a later work. On the basis of diffraction, multiple reflections, and the alteration of the ratios of the two electric vectors due to the latter, a simple theory is developed, the results of which agree well with the experimental results. The chief fact derived from the experiments is that for narrow slits the total amount of light transmitted is not, even approximately, proportional to the opening, and that therefore the use of such slits for photometric purposes will lead, unless proper corrections are made, to erroneous values for the intensity of the transmitted light.

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1 Roy. Soc. Lond. Proc. A, 89, 1913-14, p. 194.

2 Full report in May, 1921, number of Jour. of Opt. Soc. of Amer.

THE TACTUAL ANALOG OF STROBOSCOPY.

L. E. DODD

The subject of coincidences has application in stroboscopy, or the stroboscopic effect, in vision, and in the phenomenon of musical beats in audition. By means of a suitable mechanical device it applies also to the tactual sense. There may thus be produced tactual, as well as musical and optical beats.

A tactual sensation is aroused by simple pressure of a blunt point on the pad of a finger. This sensation may be given a uniformly intermittent character through periodic change in the pressure. Such a periodic change is produced by, say, periodic complete removal of the point from all contact with the skin. If the frequency of contact is sufficiently high, the sensation itself may be expected not to have an intermittent character. This condition would correspond to the rapid flashing of a light before the eyes, where the frequency of the flashes is high enough, sixteen or more per second, so that the retinal after-image bridges over the time interval between flashes. It would involve a tactual after-image.

Instead of the same blunt point pressing the finger-tip at each contact, there may be a succession of similar points having the successive contacts with the skin. The subject interprets the contacts as being due to the same point, just as in stroboscopy the eye interprets the successive similar flashes as due to the same source, whether this is true or not, as it usually is not. This is a fundamental illusion in the stroboscopic effect. The illusion is present whether or not the frequency is high enough to impart a continuous rather than an intermittent character to the sensation.

If, in the case under discussion, the successive blunt points have contact at slightly different places along a line proceeding in a definite direction, the subject will interpret the sensation as due to the same point moving in that direction.

A mechanical device producing this tactual analog must furnish the series of blunt points,—corresponding to stroboscopic "figures" (as distinct from the "images"),—and a means for bringing these into contact with the finger end, in the simplest case one at a time. The two characteristic frequencies will thus be found in that of the points, where points successively displace others, and in that

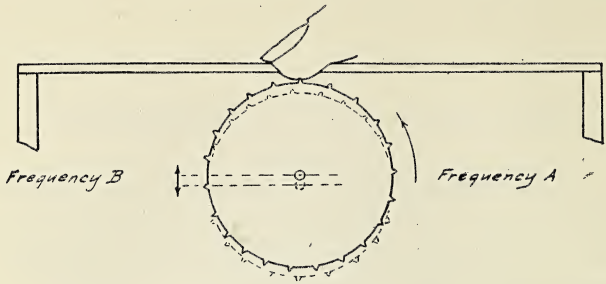

Fig. 26

of the part of the mechanism causing tactual contact. The accompanying sketch gives one scheme for such a device, (Fig. 26), which may be called a tactostrobe.

Physics Laboratory
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HALL EFFECT IN THIN SILVER FILMS.

J. C. STEINBERG

(Abstract)

The Hall Effect as a function of thickness has been investigated in chemically deposited films of silver, of thickness ranging from 40 to 200 millimicrons, and the Hall Coefficient found to be independent of both magnetic field, for fields up to 20000 Gauss, and thickness. The specific resistance of the same films increases as much as 200 per cent for some of the thinner films. These results are in good agreement with those obtained by Dr. G. R. Wait last year.

Observation would seem to indicate that the Hall Effect depends primarily upon the mass per unit area, rather than upon the particular manner in which the particles of silver are deposited, provided that the arrangement is sufficiently irregular to annul the possible effects due to the magnetic field of the atom. Irregularities in the mass per unit area, which are practically unavoidable in the chemical deposition method, account for much of the rather large experimental error.

In order to test these observations, the work is being extended to films secured by evaporating silver wire, whereby it is hoped to secure a more uniform mass per unit area and a different film structure. Attempts at crystalline growth in films probably will be made in order to find the effect of crystalline arrangement. There is considerable evidence that much of the explanation of disagreement between Electron Theory and experiment, may be found in considering the neglect of the theory to take into account the position of the electron in the space lattice of the crystal.

PHYSICAL LABORATORY,
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THE ALPHA LINES IN THE "K" SERIES TUNGSTEN SPECTRUM

CHARLES CROFUTT

(*Abstract*)

According to Bohr's theory of the atom, radiation takes place only when an electron goes from one orbit to an orbit closer the nucleus. If W represents the energy associated with an orbit, that is, the energy required to remove an electron from the orbit to infinity, the energy radiated when an electron goes from orbit (1) to orbit (2) will be $W_2 - W_1 = h$, where orbit (2) is closer the nucleus. Assuming that an absorption frequency corresponds to the energy associated with a ring of the Bohr atom, the difference between two absorption frequencies should give an emission frequency.

Duane has measured one absorption frequency in the K region and three absorption frequencies in the L region. The difference between the K absorption frequency and the L_1 and L_2 absorption frequencies respectively gives the $K\alpha_1$ and the $K\alpha_2$ lines. The difference between the K absorption frequency and the L_3 absorption frequency gives a result very close to the frequency of the α_2 line. Duane did not succeed in resolving this $K\alpha_2$ "doublet." However, he did obtain evidence that it was a doublet. The peak obtained by him, using the ionisation method, was broader on one side than on the other.

The present work was begun with the object of obtaining this α_3 line by means of the photographic method. The resolving power of the X ray spectrometer was increased by using thin crystals, narrow slits, a greater distance between the crystal and the photographic plate, and by working on the second and third orders. This made it necessary to considerably prolong the time of exposure, in one case 11 days continuous operation. The front slit was .005 cm. in width and the thicknes of the crystal was .015 cm. The distance between the crystal and the plate holder was 60 cm. Since the α_3 line was not obtained on any of the plates the results seem to indicate that the intensity of the α_3 line is less than .1 that of the α_2 line, or it differs in wave length by less

than .05 per cent. It is entirely possible that it could be obtained under more favorable circumstances.

PHYSICAL LABORATORY
STATE UNIVERSITY OF IOWA

THE BLACKENING OF A PHOTOGRAPHIC PLATE AS A FUNCTION OF INTENSITY OF MONOCHROMATIC LIGHT AND TIME OF EXPOSURE

P. S. HELMICK

(*Abstract*)

By an empirical modification of Hurter and Driffield's[1] and Ross'[2] formulæ, it has been possible to express the blackening of a photographic plate exposed to monochromatic light as a function of intensity of light and time of exposure with an accuracy within the limits of the experimental data at hand. By means of monographic charts the constants of the equations can be computed by semi-graphical methods.

The equations used were:

$$D = \frac{1}{a} \log_e \left[b - (b-1)\, e^{-(10^A\, t\, I^{\, B + C \log_{10} I})^{\frac{1}{k}}} \right]$$

and

$$D = \frac{1}{a} \left[1 - \frac{1}{n} \sum_{s=o}^{s=n-1} e^{r^s (10^A\, t\, I^{\, B + C \log_{10} I})^{\frac{1}{k}}} \right]$$

where D is the density of plate

$$\left(\text{density equals } \log_{10} \frac{\text{incident light}}{\text{transmitted light}}\right),$$

I is the intensity of monochromatic light, and t is the time of exposure to light.

The p of Schwarzchild's[3] formula for equal blackenings of a photographic plate: It^p equals constant; can be found from the above formulae as $(B + C \log_{10} I)^{-1}$.

THE PHYSICAL LABORATORY,
THE STATE UNIVERSITY OF IOWA.

1 Journ. Soc. Chem. Ind. 9, 455; 1890.
2 Journ. Optical Soc. of Am., 4, 261; 1920.
3 Astrophys. Journ., 29, 154; 1909.

THE SOLAR SURFACE DURING THE PAST THIRTEEN YEARS—A REVIEW OF SUN-SPOT OBSERVATIONS MADE AT ALTA, IOWA, FROM 1908 TO 1920.

DAVID E. HADDEN

My last paper contributed to the Academy of Science on solar observations covered the period 1903 to 1907 and was published in the Proceedings for 1908, Volume XV. The present paper brings the observations down to the close of 1920 and completes a series embracing thirty years of sun-spot observations. They do not pretend to be as complete during the last decade of this long period as for the first twenty years for the reason that I was appointed a member of the State Pharmacy Board in 1909, serving eleven years, and the duties of the office called me away from home very frequently, consequently the number of days on which the sun could be observed was materially diminished each year. The observations represent the result of painstaking work during the intervals snatched from a busy business life and are presented to indicate what may be done by anyone, even if handicapped by numerous other duties, in this fascinating branch of astronomy.

The instruments used in the thirteen years' record were a 5½ inch refracting and occasionally a 9½ inch reflecting telescope, using Herschelian and polarizing eye pieces, grating spectroscope, position micrometer and various other necessary accessories.

1908

Decreasing activity which set in during the closing weeks of 1907 continued during the first three months of this year, but a revival took place in April and some fine spots were seen. The greatest activity of the year occurred in August and September, the giant spots being easily seen with the naked eye. Diminishing activity and some spotless days marked the closing months.

1909

There was only a slight reduction in the average monthly numbers of groups, spots and faculae this year as compared with those of 1908. Large spots were present on the disc nearly every month, the exception being June, August, November and December. By far the most interesting spots of the year were in September, when large and active ones were present and on the 25th remarkable electro-magnetic disturbances were reported in the daily papers as existing all over the United States and Great Britain, interrupting telegraphic and telephonic service.

1910

A marked decline in numbers of groups, spots and faculae was noted this year, and the number of spotless days greatly increased. The months of February, May, September and October recorded the largest and most interesting groups, those of September and early October being of the train or stream character and of great extent. The closing two months of this year registered the least number of spots for a longer period than any other of the present cycle.

1911

The quiescent period noted above continued almost all of this year. At no time of observation, with one exception in April, were there more than two groups of spots present on the disc and all were relatively small, fully one-half the total number of days of observation revealing an absence of dark spots.

1912

During this year, as in the preceding one, the sun's surface was very quiet, nearly three-fourths of the days being free of spots. The faculæ also showed a marked diminution and the actual minimum of the cycle was near at hand.

A few of the larger spots were traced during several rotations. That of March 8 reappeared early in April and was spectroscopically active and increased to a considerable group. It reappeared for the third time early in May. A typical normal spot was present in June and some of the two-spot variety were present in October and December.

1913

This year undoubtedly marked the end of the minimum period, which must have been passed by the middle of the year, although it has been prolonged so much that it may be difficult to locate the period precisely.

A small spot with outliers was seen in high north latitude about February 23, which may mark the beginning of the new cycle. Some dots also in the same latitude in July would indicate that the forces originating the new cycle of activity were already at work. Eighty-five per cent of the observing days were devoid of spots.

1914

There was a noticeable revival of activity this year. Observations in February were few owing to intense cold, frequent storms and unsteady air. A very fine spot was on the disc from 13th to 26th of August, visible to the naked eye in the northern hemisphere. It reappeared by solar rotation for the second transit of the disc about September 9, although it was much smaller, disappeared on the 22d and did not again appear in succeeding rotations. However, the location was marked by large faculæ in October.

1915

The first three months of this year were characterized principally by small groups of small spots, but at the beginning of April the forces concerned with the ushering in of the period of maximum activity began to assert themselves and a giant group in the form of a long train of large spots fully 175000 miles in length and visible to the naked eye made the transit of the disc in the northern hemisphere. This disturbance reappeared for several solar rotations though in decreasing area and activity, and in May the sun was free of spots for several days. About the middle of June brilliant Auroras and earth currents interfering with the telegraph service over the United States were coincident with another outbreak of active spot regions and during part of July and August fine groups were observed in the northern hemisphere. These gradually declined in activity and the balance of the year was about normal for the period.

1916

There was a gradual increase in activity during the first six months of this year with fairly large spots present each month, the fine group of the last week in May being of a wonderfully intricate appearance. The month of June also witnessed a disc covered with smaller spots. A decrease was noted during the next three months, followed by some revival in October, November and December. On the night of August 26 an aurora of surpasing beauty and interest was observed, being one of the finest I have seen for twenty-five years. A boreal crown with colored beams and streamers, double arches and curtains were part of the wonderful display. It is of interest to note that this aurora occurred when the visible disc was practically free of sun-spots.

1917

This year was noted for:

1. The presence of large spots almost continuously throughout

the year, those of February, August and September being of giant magnitudes. The great spot of August was noteworthy for its intricate penumbra containing numerous large umbræ and nuclei, and the auroras which were coincident with its passage across the disc.

2. The greatest activity of the present cycle seems to have culminated in the months of August and September and undoubtedly the maximum was passed by the month of October, as a period of lesser activity had then set in.

1918

1918 opened with numerous spot groups on the disc, many of which were large, but the number gradually waned until June when they were fewer and of much smaller size. A slight increase in numbers took place in July and August, but this diminished during the balance of the year, although with large spots still on the disc every month. Auroras also were quite frequent this year.

1919

There was but a slight reduction in the average number of groups per day in 1919 as compared with the preceding year. The first half was the more active, the number reaching a maximum in June and gradually waning during the latter half.

1920

A decided decline in numbers of groups was noted this year, the average per day for the year being slightly over one-half less than in 1919. Nevertheless some very large active groups were observed, perhaps the finest being the one of March 15 to 27, which extended nearly 250,000 miles and was exceedingly active. Its passage across the central meridian was nearly coincident with a wide-spread display of aurora on the 22-23d.

Some spotless days were noted in April and August. In September another period of considerable activity set in, some fine large spots and extended streams being noted. These continued into October, after which a quiescent period again set in.

In the following tables are given the monthly summaries of the daily observations:

Months	Average number of Groups	Spots	Faculae
1908			
January	3.3	13.3	3.3
February	2.3	6.4	3.4
March	2.7	8.0	3.1
April	3.9	15.5	2.8
May	3.1	9.1	3.0
June	3.3	12.6	3.1
July	3.1	12.8	3.4
August	4.5	22.5	4.4
September	5.4	22.6	3.8
October	2.4	6.0	4.0
November	3.3	14.4	3.2
December	3.3	12.5	3.3
1909			
January	4.6	18.8	3.3
February	4.0	21.2	3.7
March	3.3	20.0	3.6
April	1.8	6.8	2.4
May	2.3	11.5	2.4
June	2.4	7.4	2.8
July	2.5	10.2	2.5
August	2.3	8.0	3.0
September	2.2	10.1	2.5
October	4.1	14.0	3.3
November	...	...	...
December	...	...	...
1910			
January	2.0	4.0	3.0
February	1.6	10.0	1.8
March	2.0	7.1	2.0
April	0.8	1.4	1.0
May	1.7	6.2	1.9
June	1.0	3.7	1.6
July	1.1	3.1	1.8
August	0.8	2.9	2.0
September	2.0	7.0	2.0
October	2.0	11.3	2.0
November	0.4	0.8	2.0
December	0.4	2.0	1.2
1911			
January	0.5	0.5	1.1
February	0.8	2.3	1.4
March	0.8	3.3	1.0
April	1.2	2.6	1.2
May	0.8	3.0	1.6
June	0.4	1.0	1.0
July	0.5	2.0	1.0
August	0.7	1.4	1.1
September	0.6	1.5	0.7
October	0.3	0.8	0.8
November	0.6	1.0	0.5
December	0.3	0.3	0.9
1912			
January	0.0	0.0	0.2
February	0.1	0.1	0.3
March	0.4	1.5	0.5
April	0.6	3.8	0.5
May	0.4	3.1	0.5
June	0.9	0.9	1.1
July	0.4	2.3	1.0
August	0.1	0.1	0.4
September	0.5	4.5	1.4
October	0.3	1.7	1.1
November	0.2	0.4	0.5
December	0.4	2.8	0.6
1913			
January	0.3	0.5	0.6
February	0.1	0.3	0.2
March	0.0	0.0	0.0
April	0.2	0.8	0.2
May	0.0	0.0	0.1
June	0.0	0.0	0.0
July	0.1	0.3	0.2
August	0.0	0.0	0.7
September	0.2	1.0	0.3
October	0.2	1.5	0.2
November	0.1	0.3	0.3
December	0.5	2.5	0.8
1914			
January	0.0	0.0	1.2
February	0.3	1.5	0.5
March	0.3	0.6	0.7
April	1.0	4.1	1.1
May	0.6	2.6	1.6
June	0.7	4.9	1.4
July	0.7	1.8	1.3
August	0.8	3.0	1.1
September	1.9	3.7	1.8
October	0.8	3.4	1.7
November	1.7	9.9	2.3
December	2.6	6.7	2.3
1915			
January	1.7	6.8	3.2
February	3.8	21.5	3.6
March	1.7	5.3	3.3
April	2.8	18.7	3.6
May	1.2	6.4	3.0
June	4.3	36.4	2.9
July	3.5	18.3	4.2
August	4.3	20.6	4.0
September	3.0	17.6	4.6
October	3.9	22.8	3.7
November	3.6	13.2	3.8
December	2.5	9.1	4.0
1916			
January	3.5	18.7	3.4
February	6.0	15.7	3.0
March	5.0	31.2	3.8
April	4.4	28.8	4.6
May	5.8	28.0	4.2
June	5.3	34.7	4.0
July	3.3	12.0	3.3
August	2.0	7.0	4.0
September	3.2	14.5	3.3
October	5.5	15.7	4.0
November	4.1	24.6	4.9
December	5.5	29.5	4.0

The telescope was partly dismounted for repairs during the months of November and December, 1909, and January, 1910.

During the years 1917 to 1920 owing to the war and scarcity of business help, numerous absences from home, personal losses by deaths, etc., the time devoted to the work was necessarily limited and the full daily observations not completed, hence only the daily average number of groups are given in the following tables:

AVERAGE DAILY NUMBER OF GROUPS

MONTHS	1917	1918	1919	1920
January	6.7	6.8	4.0	2.0
February	5.0	4.8	5.3	4.0
March	6.8	5.2	4.8	3.0
April	6.5	5.7	4.2	1.5
May	7.0	5.5	5.3	3.0
June	8.3	4.8	7.0	2.4
July	8.5	6.9	4.6	
August	10.0	6.7	4.7	1.4
September	9.0	5.6	4.4	1.7
October	5.2	5.9	4.2	3.4
November	6.9	5.7	2.9	2.0
December	7.5	4.8	2.8	1.8

Reviewing the observations of the thirty years which embraced three maximum and three minimum periods, the following dates have been derived:

Minimum of 1889.6 to the maximum of 1893.7	4.1 years,
Maximum of 1893.7 to the minimum of 1901.5	7.8 years,
Minimum of 1901.5 to the maximum of 1905.9	4.4 years,
Maximum of 1905.9 to the minimum of 1913.5	7.6 years,
Minimum of 1913.5 to the maximum of 1917.7	4.2 years,
Minimum of 1889.6 to the minimum of 1901.5	11.9 years,
Minimum of 1901.5 to the minimum of 1913.5	12.0 years,
Maximum of 1893.7 to the maximum of 1905.9	12.2 years,
Maximum of 1905.9 to the maximum of 1917.7	11.8 years,

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THE 1921 OUTBREAK OF THE CLOVER-LEAF WEEVIL IN IOWA

H. E. JAQUES

Early in the spring of 1921 it became apparent that many clover meadows were suffering severely from some trouble. The entire stand was killed in an occasional field while in others patches throughout the fields were killed or the plants were very much stunted. At first it was thought by many to be winter-killing but it was soon found to be insect injury due to the work of the Clover-leaf Weevil, *Hypera punctata* Fab., and one or more species of cut worms. It was thought in some quarters that the matter was further complicated by the presence of a fungus disease of the roots. As far as the writer observed this root injury seems to have been an infection naturally following the insect damage.

The clover-leaf weevil, which originally came from Europe, has been known in this country for a half century or longer. It can be found almost any season in almost any clover field but has never before been known to do such general and widespread damage within the state of Iowa as during the spring of 1921.

The clover-leaf weevil has but one brood per year. The eggs are laid on various parts of the clover or alfalfa plant. A good percentage of the eggs hatch and reach the first, second or third instar as larvæ before hibernating. The later eggs do not hatch until spring. The larvæ are yellowish green or bluish green (a small percentage pinkish) with a white dorsal stripe and when fully grown measure from 1/3 inch to a little more than 1/2 inch in length. Cocoons with a unique golden brown silky network covering are formed on or immediately under the ground, pupation occuring in May or June. The adult, a brown snout beetle, begins to emerge in June and many continue to live until winter sets in or later.

They were found feeding on the common red clover and on alfalfa although the injury to the clover was much the worse. The leaf blades and petioles and the more tender stems of the plants were eaten. In many cases the crowns of the plants were literally filled with the larvæ.

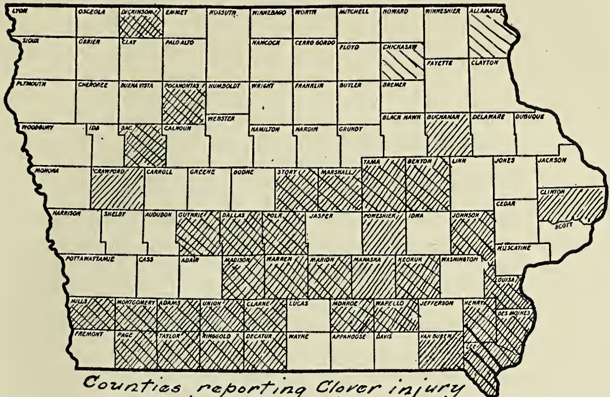
Counts of weevils were frequently made. It was not uncom-

Fig. 26a. Worms on a denuded spot in a meadow.

mon to find thirty or more larvæ feeding on one clover plant. Mr. A. E. Albert living north of Eldon had 65 acres of clover which was almost wholly killed. A part of this meadow was already plowed when we visited it. Many weevil larvæ could be seen in the furrows. A count of the larvæ was made for five feet of furrow which averaged 108 worms to the foot in length of furrow.

The cutworms (species undetermined) seemed to do even worse damage to the clover than the weevils though the two pests worked together for the most part. The cut worms ate deeper into the plant crown. County agents and farmers in the infested areas were about evenly divided in their opinion as to which of the two insects was the more destructive. The map shows the counties of the state in which damage was known to occur.

The extent of damage was highly variable in the different regions. In some areas the damage was light and of only a temporary nature. It was seen as summer came on that many fields made a much better recovery than had been thought possible. Some counties suffered heavilv, the stand being so completely killed that many meadows were broken up. Since this came in a year with an already too large acreage of corn the loss was even greater than would seem at first.



Counties reporting Clover injury during the spring of 1921.
Clover Leaf Weevil
Cutworms

Two small alfalfa fields in Des Moines county were sprayed with arsenate of lead in much the same manner as is employed in the western states to control the alfalfa weevil. The county agent reported that apparently 90 per cent of the worms were killed in one field and that the alfalfa made an excellent recovery. The application of the poison was followed by rain at the other field and in consequence the results were not so favorable.

For the most part no control measures were attempted. The weevil larvæ are ordinarily highly susceptible to a fungus disease but during the season of 1921 much damage resulted before the fungus became operative and in some areas but a small percentage of the larvæ seemed to be killed in this way.

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A BALTIMORE ORIOLE CENSUS

KATHERINE GILMORE AND H. E. JAQUES

The question with which this article is concerned is one that was under discussion in the Ornithology Class at Iowa Wesleyan College. The original problem was to discover how many pairs of Baltimore orioles nest yearly in the town of Mount Pleasant where the college is located. As the investigation was carried on and interest deepened, the scope of the problem was enlarged somewhat to include a study of the determining factors in an oriole's selection of a nesting place. When the problem was first undertaken, the town, which has a population of about four thousand and covers an area of one and one-fourth square miles, was divided into six districts of about equal extent and two students were appointed to search each district for orioles' nests and to note the species of tree in which they were found. This work was done in February, and, as there were no leaves on the trees, each swinging pouch was quite conspicuous and the matter was not one of great difficulty. The complete report was as follows:

Kind of Tree	Number of Nests
Soft Maple	60
White Elm	40
Box Elder	10
Hickory	5
Cottonwood	3
Hard Maple	2
Hackberry	1
Apple	1
Walnut	1
	123

The fact that but two-thirds as many nests were found in elms as in maples seemed worthy of investigation since all available bird literature advanced the opinion that the oriole preferred an elm tree. In this matter the Botany Class assisted with a census of the elms and the soft and hard maples six inches in diameter or larger in Mount Pleasant. This second census was as follows:

Kind of Tree	Number of Trees
Soft Maples	1392
Elms	814
Hard Maples	817

When this report was investigated it appeared entirely logical that these orioles had built in the soft maples, even though their natural preference might still have been for the elm, for in some parts of the town no elms are found for a few blocks. It was also interesting to note that although the number of hard maples practically equalled the number of elms, there were but two nests found in hard maples. The orioles evidently chose the wide-spreading trees, and in almost every case they hung the nests at the very end of a flexible outer branch.

As it was thought possible that the nests might have been hanging for several seasons, each student concerned in the census taking was asked to use his own judgment in determining whether or not the nests were more than one year old. It was the general opinion that about one-half of the nests counted had been built during the preceding summer as they seemed to be in quite good condition, and the conclusion was drawn that between fifty and sixty pairs of Baltimore orioles nest yearly in Mount Pleasant. The other half of the nests appeared to be of two or three years' standing. Most of the third year's nests had probably disappeared entirely but several cases were reported where in one tree three nests were found; one very old and almost weathered away, one less battered but still showing wear, and one in good condition. They evidently represented three years' residence, and demonstrated the fact that orioles come again year after year to any favorite locality.

Later in the season, after the returned orioles had nested and the young broods had been reared the search for nests was renewed with the hope that perhaps four seasons' nests might be found together. However, though considerable time was spent in this search, it served chiefly to demonstrate the advisability of hunting orioles' nests during the winter months. The birds show admirable skill in concealing their nests from the casual observer. One new nest was obtained which hung from the lowest branch of a hackberry tree thirty feet directly above the side walk. It was cut down, and its structure and materials were examined. Its outer walls were made chiefly of silklike plant fibers interwoven with a few black horse hairs, and it was hung by loops of the same material from two small branches at the end of the limb. Its interior measured five inches in depth and about three inches in width. Its upper walls were thin, soft, and pliable, but the bottom was an inch and a half thick and very firm and solid. This substantial flooring was found to consist of numerous compact layers of different materials, ranging from coarse grasses in the lower layers to the soft down from weed seeds which made the upper lining layers.

This nest and most of the others were found within the residence districts of the town near the most frequented streets, but several blocks from the business section. Noise does not seem to bother the orioles for in one case a nest was found swinging from a low branch of a big maple not ten feet from a railroad track where a local train which passed twice a day must have caused great excitement among the young birds. The orioles seem to seek human companionship, for a vain search was made for nests in a quiet grove of old elms and maples near the edge of town which seemingly should have been an ideal nesting place. Moreover the woods around the town seemed neither to be chosen as nesting places, nor to be frequented by orioles after their return, from which facts it was inferred that the rural orioles prefer the big shade trees in the farmyard to the solitudes.

One nest was found which was notably different from the others, and which must have belonged to a very eccentric oriole family. It was hung in the woods, almost a mile from the nearest residence and in a very unfrequented place. It was also the only nest reported as being built in a sycamore tree. But its location in the tree was the most peculiar thing about it. It did not swing from a low outer branch as the other nests did, but it was placed in the very top of the tree and fastened to three small branches so that it hung in the fork that they formed. As this nest was located while occupied there is no question of correct identification.

The comparatively small amount of work which was done raised numerous most interesting questions which the limited time and opportunity made it impossible to answer. Whether the orioles that nest in one town or community during one season generally return to it during the next, whether young birds return the next year to the locality in which they were reared, are questions which might all be answered in a few years by careful banding of the young orioles in a few nests. Concerning the nest itself such questions arise as whether or not both birds are employed in the building, what different kinds of material they will use, how far away they will search for them, and to what extent their choice of materials may be governed by supplies provided for them. A season's watchfulness would answer these questions and might also reveal the secret of how the mother bird manages her household so successfully that at the end of a busy summer she leaves the abandoned home specklessly clean and tidy.

Iowa Wesleyan College
Mount Pleasant, Iowa

CORN OIL CAKE MEAL FOR GROWING AND FATTENING PIGS.

JOHN M. EVVARD AND RUSSELL DUNN*

Corn oil cake meal is really a residue of the germs of corn grain which remains after most of the oil is extracted therefrom. The particular corn oil cake meal which we used in our test is a by-product from the manufacture of glucose. These four main products are made from the corn grain: Glucose, corn oil, gluten feed, and corn oil cake meal. It is with the latter that we are to deal.

The corn oil cake meal according to approximate analyses contains approximately in every 100 pounds 9 pounds of water, 22 pounds of crude protein, 47 pounds of nitrogen-free extract, 10 pounds crude fibre, 10 pounds of ether extract, and 2 pounds of ash.

In removing the oil from the separated corn germs or embryos the separation is largely physical although the germs are heated to the scorching point in the process.

To more clearly comprehend the action of this corn oil cake meal of which there is less than 2 pounds manufactured from a bushel of corn it is well to emphasize some of the main essentials of the adequate ration for young growing and fattening pigs:

First—*The protein quantity must be large enough* in order to meet all demands for growth and general metabolism.

Second—*The protein quality must be right,* which means that there must be a correct proportion existing among the various amino acids of which there are some twenty, as well as a sufficiency of the essential ones within the mixture.

Third—*A sufficiency of minerals is of considerable importance,* otherwise the bodily mechanism which is in a growing state will be severely handicapped.

Fourth—*Mineral quality should likewise be carefully attended to* so that the apportionment of the various elements within the total mineral quantity shall be adequate in every particular—which means that there shall be, specifically speaking, just enough

[1] With the assistance and collaboration of E. J. Strausbaugh, Superintendent; D. B. Adams, Herdsman; and H. B. Winchester, Assistant.

of each of the elements present in that particular quantity—just enough of calcium, for instance, not too much nor too little, because if there is too much that may sometimes put a burden upon the animal organism, and if there is too little the inadequacy is evident.

Fifth—*There should be present fat soluble A* in large enough quantity to meet the demands of the organism—fat soluble A such as is found in butter fat, carrots, alfalfa leaves, meat meal tankage, the lighter fractions of beef fat, and the other vitamines, and so on.

Sixth.—*Water soluble B and the other vitamines should not be neglected.* They are necessary—fortunately the water soluble B is quite widely distributed. There is some question about the antiscorbutic being absolutely essential.

Seventh—*The fibre content should be relatively low.* Too much fibre is a detriment to young, growing pigs.

Eighth—*There should be an abundance of starch or its equivalent in sugars or similar materials* to furnish the energy and fattening requirements of the organism.

Ninth—*Toxic materials should not be contained within the ration,* in other words all of the ingredients should be healthful and not of toxic or poisonous character.

Tenth—*Other considerations general in character should be given attention*—such considerations as palatability, laxativeness, high digestibility, relatively high net production value, and the correct relationship between all of the various constituents, their relationship changing as the demands change—in other words as the animal grows and develops.

It can be readily seen that in considering the complete nutrition of an animal the problems arising therefrom are many and complex. The good ration can be made inadequate by the removal therefrom of a single nutritional essential such as fat soluble A or water soluble B, or certain amino acids, just as an automobile engine that is functioning properly can be totally incapacitated by the removal of the timing gear, or the piston rings, or the spark plugs, or the gasoline, or the oil, and so on. Sometimes just a small quantity of a certain material like fat soluble A will give results wholly out of proportion to its weight. The inflammable head of a match is very small but it can bring about wonderful changes under proper conditions. A catalyzer is very small in quantity but will cause changes which as compared to the catalyzer itself are of exceptional magnitude.

With the viewpoint in mind, therefore, of fitting a feed into its proper place, we undertook the investigation of the feeding of corn oil cake meal. In the first place we wanted to determine whether or not corn oil cake meal in itself was a complete ration. We found that it was not.

Pigs that were taken on June 29 at weaning time and fed until October 27, 1917—120 days—weighed 180 pounds at the close of the feeding period where corn, and tankage, and salt were allowed "Free-Choice" style on bluegrass pasture. Where corn oil cake meal and salt only were fed the final weight was only 96 pounds, thus showing that as compared to a good ration, even though the pigs getting the corn oil cake meal ran on bluegrass, corn oil cake meal was inefficient.

We tried adding tankage to the corn oil cake meal, letting the pigs have "Free-Choice" of these two feeds, but even at that the pigs on this aforementioned date of October 27, after 120 days of feeding, weighed only 134 pounds. Thus it will be seen that the addition of tankage to corn oil cake meal is not nearly so efficient as the addition of tankage, for instance to a corn alone ration. To drive this home we would simply cite an experiment now in progress. Corn alone pigs (salt was allowed) at nine months of age weighed approximately fifty pounds. These were fed in dry lot. Tankage added to this corn ration has made the same kind of pigs weigh better than 250 pounds at the same age. Just because tankage, therefore, is a good supplement to corn does not mean that it is just as efficient a supplement to corn oil cake meal, or to any other feed unless that feed be very, very similar to corn such as wheat for instance or barley or rye, yet even with each of these specific feeds tankage bears different relationships. Of course, by tankage I refer to the 60 per cent protein product which sometimes goes under the name of meat meal, sometimes tankage, again it is called meat meal tankage, or Digester tankage, but the point is that it is a meat and bone residue of a very high protein content, namely 60 per cent.

How about adding corn oil cake meal to the corn ration fed on bluegrass pasture? Instead of the pigs weighing 180 pounds as they should on good corn and tankage ration they weighed 114 pounds. This shows that corn oil cake meal, therefore, is not an efficient single supplement to corn when said corn is fed to hogs on bluegrass pasture in conjunction with salt at free-will.

The addition of a little linseed oil meal to the corn and corn oil cake meal ration was attended with slightly beneficial results, but even linseed oil meal added to this combination is not to be considered as a success—it helped a little but not much.

The addition of a limited quantity of buttermilk, however, to a corn and corn oil cake meal ration was in the interests of efficiency. Where shelled corn and tankage were fed in separate feeders the weight on October 27 after 120 days of feeding was 180 pounds, but, as mentioned, where corn oil cake meal was substituted for the tankage the weight was only 114 pounds. There is a wide range between 114 and 180, sixty-six pounds, which may be remedied by the addition of proper supplemental feeds to the corn and corn oil cake meal combination. Buttermilk was successful in increasing the weight of these pigs to 164 pounds. In this case not quite five pounds of buttermilk was fed daily per pig in addition to the shelled corn and corn oil cake meal. We do not think that there is any question that had this buttermilk, or even skim-milk—its practical equal—been added in larger quantity the gains would have been favorably increased so that they would have approximated or even have excelled the corn and tankage fed group.

In order to gain a more adequate knowledge concerning the improvement of a corn and tankage ration or a corn and hominy ration by the addition of corn oil cake meal we planned to feed six groups of pigs, placing six pigs averaging about forty-eight pounds each in weight and about seventy-seven to eighty-one days in age to a group. All groups were fed "Free-Choice" style. The test was begun June 15 and ended October 17, 1917, after 124 days of feeding.

These lots were fed:

Lot I Shelled corn self-fed plus meat meal tankage self-fed plus block salt self-fed.

Lot II Shelled corn self-fed plus a mixture of meat meal tankage 1 part, corn oil cake meal 3 parts self-fed plus block salt self-fed.

Lot III Shelled corn self-fed plus meat meal tankage self-fed plus corn oil meal cake self-fed plus block salt self-fed.

Lot IV Hominy feed self-fed plus meat meal tankage self-fed plus block salt self-fed.

Lot V Hominy feed self-fed plus a mixture of meat meal tankage 1 part, corn oil cake meal 3 parts self-fed plus block salt self-fed.

Lot VI Hominy feed self-fed plus meat meal tankage self-fed plus corn oil cake meal self-fed plus block salt self-fed.

All of the above were fed on timothy pasture, a pasture somewhat comparable to bluegrass under our conditions — really not a good pasture from the standpoint of a lone pasture supplementing corn.

The hominy feed which we used is that by-product from the corn meal mills; after the corn meal is removed for human consumption there remains the bran of the kernel, the germ (from which the oil has not been extracted), and the whiter, starchier portions. In reality the hard, flinty portion of the kernel has been removed and this has been milled into corn meal for human consumption; all of the rest of the kernel, therefore, goes back to the farm for live stock feed in Hominy Feed Sacks.

It will thus be noticed that in this particular product, hominy feed, there is really a concentration of germs due to the fact that the flinty portion of the kernel has been removed. We would hardly expect, therefore, to have as good results from the addition of corn oil cake meal to a hominy ration fed in conjunction with tankage as we would by adding the same feed to a corn tankage ration, providing, of course, the ingredients of the embryos or germs themselves were advisable or necessary in such combination.

Table I given herewith gives the agerage initial weight per pig, final weights (these at approximately 203 days), average daily gain, average daily feed, and feed required for a hundred pounds of gain.

TABLE NO. I

Lot. No.	I	II	III	IV	V	VI
Average Initial Weight per Pig	47.9	48.8	49.0	48.5	48.7	49.6
Average Final Weight per Pig (at approximately 203 days)	188.6	198.7	218.7	203.1	196.0	190.8
Average Daily Gain per Pig	1.13	1.21	1.37	1.25	1.19	1.14
Average Daily Feed per Pig.						
Corn, Shelled	4.05	3.87	4.68	...	...	...
Hominy Feed	...	...	...	4.77	4.01	4.59
Corn Oil Cake Meal	...	.82	.09	...	.62	.10
Tankage	.48	.27	.55	.38	.20	.25
Salt	.00	.00	.00	.00	.00	.00
Total	4.52	4.96	5.32	5.15	4.84	4.93
Feed Required for a 100-lb gain:						
Corn, Shelled	356.5	319.8	342.2	.....	....	....
Hominy Feed	....	....	....	382.4	337.7	403.2
Corn Oil Cake Meal	....	67.7	6.6	....	51.9	8.4
Tankage	42.2	22.6	40.1	30.3	17.3	21.6
Salt	0.0	0.2	0.0	0.0	0.2	0.0
Total	398.7	410.3	388.9	412.7	407.1	433.2

Before discussing this table which takes all groups of the pigs to the same date (Oct. 17, 1917—124 days feeding) it is well to introduce another table, namely Table II, which figures all the groups to the same weight, or approximately 189 pounds. This gives us better material for comparison. Table II, therefore, puts all groups upon a similar basis in that a definite sized pig is produced, taking them all at approximately the same size, namely forty-eight pounds at weaning time. In this table is given the average final weight, number of days required to reach the weight of approximately 189 pounds, average daily gain, and feed required for a hundred pounds of gain.

TABLE NO. II

Lot. No.	I	II	III	IV	V	VI
Average Final Weight	188.6	189.8	189.5	189.5	188.9	190.8
No. Days Required to Reach Weight	124	116	104	114	119	124
Average Daily Gain	1.13	1.22	1.35	1.24	1.18	1.14
Feed Required for a 100-lb Gain:						
Corn, Shelled	356.5	309.5	321.1	....	....	....
Hominy Feed	....	....	....	370.1	336.3	403.2
Corn Oil Cake Meal	....	57.6	5.6	....	53.1	8.4
Tankage	42.2	19.2	43.2	30.7	17.8	21.6
Salt	0.0	0.10	0.0	0.0	0.2	0.0
Total	398.7	386.4	369.9	400.8	407.3	433.2

Note that in Table II the feed required for a hundred pounds of gain in the "shelled corn groups," namely I to III, was decreased by the addition of corn oil cake meal in both instances. Where the pigs were "camouflaged" a bit by mixing the corn oil cake meal with the tankage (group II) they took 8 days less time to reach the necessary weight than where just the straight corn and tankage was used and practically twelve pounds less feed was required for a hundred pounds of gain. In Group III where these three feeds were all fed "Free-Choice" style twenty days were saved and practically twenty-nine pounds of feed.

This shows quite clearly that under the conditions of this experiment with young growing pigs corn oil cake meal when added to the corn and tankage ration fed on timothy pasture in conjunction with salt apparently supplied some deficiencies because the pigs on account of such addition gained rapidly and required less feed to make the same amount of gain.

Now why was Group II camouflaged? Remember that the pig is a physiologist and that he eats to suit himself and not his owner; therefore, it may be necessary to make certain mixtures so that the growing and fattening process will be advantageous to the owner of the pig. It is only by the proper balancing of the physiological and economical aspects of the pig feeding game that we can come to a correct solution of our problems in practice. Both the pig and the man must be considered.

The comparison of the camouflaged Group II with Group I shows that a hundred pounds of corn oil cake meal saved eighty-one pounds of corn and forty pounds of tankage, a total of 121 pounds of feed concentrates. Counting the corn at $1.12 a bushel and the tankage at $100.00 a ton, current quotations in January, 1918, this 100 pounds saved $3.62 of these feeds, or a ton was worth $72.40, substitutionally speaking. With corn at $1.68 and tankage at $100.00 a ton the corn oil cake meal substituted $4.43 worth of corn oil tankage, or a ton of it was worth $88.60 on this basis.

Comparing Group III with Group I we find that a hundred pounds of corn oil cake meal saved 63.2 pounds of corn and 18 pounds of tankage, a total of 81.2 pounds of these feeds. With corn at the lower price mentioned, a hundred pounds was worth $2.10; and a ton, $43.28. With corn at the higher price, a hundred pounds was worth $2.80 and a ton $55.92—these figures on the substitutional basis.

Now what happens when we add corn oil cake meal to hominy feed is shown in Groups IV, V and VI. In V we added it in the same manner as to II. In this case a hundred pounds of corn oil cake meal mixed with tankage in the proportion of 3 to 1 and fed in conjunction with hominy feed as compared to hominy feed and tankage saved 82.7 pounds of corn and 24 pounds of tankage, a total of 107.6 pounds, not quite so good a showing. With corn at $1.12 and tankage at $100.00 a ton, a hundred pounds of corn oil cake meal was worth $2.85 and a ton was worth $57.08. With corn at $1.68 and tankage at $100.00, a hundred pounds substituted $3.68 worth of these feeds, or a ton substituted $73.62 worth.

Where corn oil cake meal was fed "Free-Choice" style in Group VI as compared to none being fed in Group IV there was a minus value for the corn oil cake meal. Just what the significance of this is we do not know but we hope to repeat the test and see if it will check. We are inclined to believe that this particular group for some reason was not quite so efficient even though scrupulous care was taken to divide all equally. These suspicious discrepencies happen even though all care and precaution is taken to divide the groups equally. We find inherent differences. It is up to the experimentalist to determine what these differences are, and what causes them, and to learn the remedy. So long as they exist and so long as we do not know why they exist, then just that much longer they must exist because we do not know the necessary weapons with which to offset them.

Briefly speaking, our more favorable general deductions from the experiments we have run thus far are:

First—Corn oil cake meal added to a corn and tankage ration is quite efficient—it saves considerable corn and tankage when properly fed. The mixture of corn oil cake meal with tankage looks favorable, and under certain economic conditions should be more favorably considered than "Free-Choice" feeding.

Second—Corn oil cake meal takes the place of tankage up to about half of the daily allowance; in other words it displaces half of the daily tankage fed. On the basis of a hundred pounds of gain it really displaces somewhat more than half the tankage, this being particularly true when it is added to a corn and tankage ration, although this is not true when the meal is added to a hominy and tankage ration.

Third—Corn oil cake meal seems to fit in excellently with the corn and tankage ration; largely, we think, because it supplies certain deficiencies in said ration.

Fourth—Hominy feed, which is really corn concentrated in bran and germs and starch through the removal of the flinty portion or the gluten of the kernel, shows up quite well in comparison with corn, although our tests have not shown it to be the equal of corn.

Fifth—Hominy feed requires less tankage daily than does corn or approximately four-fifths as much. On the basis of pounds tankage to feed with a hundred pounds of corn or hominy the latter requires about 2/3 as much as the former; or if twelve pounds balanced a hundred pounds of corn then about eight pounds would do for hominy feed.

Sixth—In such a nutritional complexity we find in all our rations for pigs we must expect that even with our best rations there is a certain limiting factor or factors, and the addition of this or these factors will tend to make the ration more efficient not only in increasing daily gains but in decreasing the feed required for a unit of gain. Animal Husbandmen should always be on the lookout for the "long-comings" as well as the shortcomings of rations. If a ration is deficient in certain particulars then through the use of the proper feed which supplies these deficiencies, and this in the proper quantity, the ration may be improved. It is well to keep in the front line trenches so as to catch a clear vision of the possibilities of correct combinations.

Hart, of the Wisconsin Station, deducting and reasoning from some of his livestock experiments, has this to say about the germs of corn: "it is necessary to attribute to the proteins of the embryo of this grain (corn) a high efficiency." This means that under certain conditions the proteins of Corn Oil Cake Meal are highly efficient, as for instance when we feed this feed in combination with tankage (or milk or alfalfa pasture or rape pasture) and corn. It seems to fit in nicely and save protein, that is, a pound of such combined proteins goes further.

Osborne and Mendel of the Connecticut Agricultural Experiment Station and Yale University respectively, in speaking of corn germs say: "We have found that the corn germ contains proteins which are superior in promoting growth to those found in the endosperm (other parts of the kernel including the bran). Further, they say: "When supplemented with a small amount of meat proteins Corn Germ is capable of inducing very rapid growth. It is also rich in the water soluble vitamine."

The absence of the water soluble vitamine from foods, such as polished rice, for instance, causes a disease of the nervous system, known as polyneuritis, which literally translated means a disease or inflammation (itis) of many (poly) nerves (neür). Degerminated Corn is lacking in this essential vitamine. Naturally, therefore, we believe that the substance was removed by this process in the germ. Voegtlin and Myers of the Hygienic laboratory of the U. S. Public Health Service have recently shown that pigeons fed on whole corn do not get this disease, but when the germs are removed with a pen knife and the balance of the kernel fed to those pigeons, this disease with its unfortunate symptoms of paralysis, and later, often quite soon, death, appears. The difficulties come in a couple of weeks following the change from whole corn grain to the germ free corn. They say: "the germ or embryo of the . . . corn kernel contains all of the antineuritic vitamine of the grain."

When we add Corn Oil Cake Meal to the corn-tankage ration we believe that there is improved thereby: first, the protein quality, this allowing tankage to be markedly saved; second, the vitamine content of the ration.

It is always well to allow before pigs a mineral mixture in which common salt and limestone (or air slacked lime) are the principal ingredients, also to put pigs on good leafy green pastures. Thus we tend to play safer with our pigs and more securely with our pocket books.

SOME DONT'S ARE IN ORDER

Don't try to feed Corn Oil Cake Meal as the lone feed. Tankage alone is bad, so is corn alone for young stock.

Don't use Corn Oil Cake Meal as the lone supplement to corn in dry lot. Mix it with tankage, or fish meal, or milk, skimmed or buttermilk.

Don't attempt to make Corn Oil Cake Meal take the place of corn or other basal grains as a full substitute because it is primarily a supplemental not a basal feed. It won't give good results alone, even though fed with tankage—allowing no other feed or feeds. If it is fed with tankage alongside corn or barley or other good basal feed, the results are pleasing because the gains and feed requirements are satisfactory.

Don't think that just because Corn Oil Cake Meal makes a nice creamy textured, bulky slop of good appearance the mere slopping (mixing with water) will take the place of good supplemental feed boxes. It won't. Use it with tankage or meat meal, or fish meal, or the milks when it is supplementing the ordinary feeds of the farm. Or else feed on good clover or alfalfa pastures in summer season.

Don't forget that Corn Oil Cake Meal mixed with skim or buttermilk is a splendid combination for balancing the farm grains—in the absense of milk, use tankage or fish meal product. Corn Oil Cake Meal makes the limited milk on the average farms go much further and that efficiently.

Don't fail to bear in mind that the average of three Iowa Station experiments showed that it took 90 per cent as much protein for 100 pounds gain where Corn Oil Cake Meal was mixed with tankage and fed with corn as where the tankage was fed straight with corn. This indicates that 100 pounds of corn—Corn Oil Cake Meal—and tankage mixed proteins are practically equal to 111 pounds of mixed corn and tankage proteins or the addition of Corn Oil Cake Meal makes all the proteins fed about 10 per cent more efficient. In case of brood sows alfalfa mixed with Corn Oil Cake Meal helps it out a great deal in its grain supplementing virtues.

Don't confuse Corn Oil Cake Meal with Corn Hominy Feed. They are very different. A good hominy feed is a splendid corn substitute—our tests showing it to equal in feeding value per 100 pounds about 80 to 100 pounds of good dry whole corn grain. Hominy Feed contains Corn Bran, Corn Starch and Corn Germs. Quite often the oil is extracted from the germs. It is the by-product of table corn meal or hominy grit manufacture. It carries less than half as much protein as the Corn Oil Cake Meal. Less tankage is required to balance Hominy Feed than corn for pigs, about 2/3 as much being required. This tankage saving virtue is presumably due to the small proportion of corn germs in this feed, about two to three times as much as in corn. But a sack of Corn Oil Cake Meal carries the germs (from which much of the oil has been mechanically pressed) of practically 50 bushels of corn or 2800 pounds. Corn Oil Cake Meal is at least twenty-five times as rich in corn vitamines and corn proteins as is good hominy feed. Some hominy feeds, however, run very low in Corn Oil Germ Meal because the Corn Oil Germ Meal commands a higher price than the hominy feed per ton, hence the financial temptation to sometimes not replace all of the oil—extracted germs that naturally remain in the residues resulting from corn meal and grits manufacture. Hominy feed is a good corn substitute whereas Corn Oil Cake Meal is a good protein and vitamine supplement to corn.

Don't expect that a mixture of Linseed Oil Meal and Corn Oil Cake Meal will be taken too readily from a self-feeder, when allowed in addition to corn or other basal grain. The palatability and effectiveness of the mixture can be greatly improved by the addition of tankage in these proportions: Corn Oil Cake Meal 50 parts (5 sacks), tankage 30 parts (3 sacks), and Linseed Oil Meal 20 parts (2 sacks) by weight. The Corn Oil Cake Meal may be mixed with wheat middlings and oil meal and fed to advantage on green leafy pastures of young alfalfa, the clovers, rape and bluegrass. If pastures get sparse or scarce, or hard and dry, add tankage, or fish meal, or milk for greatest efficiency. Of course, a little skimmilk or buttermilk with all of these mixtures is of special merit—and so fed a bucketful will go much further, and that pleasingly.

Don't forget that before the World War European Countries took practically all of the American yield of Corn Oil Cake Meal — shipping it over two thousand miles by rail and water to the feeding places, and why? Because they knew how to feed it, and what it was worth. Now that we in America have learned how to feed this feed to advantage, it is to our interest to be in the competitive market at all times — taking full advantage when the economic returns warrant.

Don't expect the pigs to eat Corn Oil Cake Meal to best advantage out of a self-feeder when allowed free-choice alongside of a basal grain such as corn, barley, wheat, kaffir corn, and other similar feeds, and a good protein and mineral supplement like tankage. Better mix the Corn Oil Cake Meal with a high-grade meat product, or a fish product to insure consumption and economy. The pig's appetite is sometimes fallible.

Don't neglect or forget, nor fail to heed these simple, effective don'ts — else your Corn Oil Meal will not yield you the maximum returns that you are so diligently and persistently seeking.

Animal Husbandry Section
Iowa Experiment Station.

NOTES ON THE MAMMALS OBSERVED IN MARSHALL COUNTY, IOWA

IRA N. GABRIELSON

Few specific locality records for mammals in central Iowa have ever been published. The following brief notes, therefore, have been prepared for the purpose of making available for future workers on Iowan mammalogy the information I am able to give. This list is not complete but comprises only such notes and specimens as came to my hands in one way or another during three years' residence.

1. Opossum. *Didelphis virginiana*

A small boy brought an opossum to me on November 4, 1914. He had caught the animal in a trap and wanted to know what it was as neither he nor his father had ever seen anything like it.

2. Flying Squirrel. *Glaucomys volans volans*

Common in the timber near Marshalltown. At different times I had two individuals in captivity and they made the most interesting pets I ever had. November 17, 1914, a single individual was brought to me by a hunter. On December 12, 1914, a dead adult and a live, partly grown, young one were secured by a companion on a hunting trip and given to me.

3. Western Fox Squirrel. *Sciurus niger rufiventer*

Common, especially within the city limits of Marshalltown, where half wild ones lived along the streets. One living near my home very frequently came and perched on my shoulder to ride along the street for some distance.

4. Gray Chipmunk. *Tamias striatus griseus*

Common in the timbered sections along the Iowa river and Linn creek. Several were brought to me alive at different times by members of the high-school classes.

5. Thirteen-lined Ground Squirrel. *Citellus tridecemlineatus tridecemlineatus*

Common throughout the pasture lands of the county.

6. Franklin's Spermophile. *Citellus franklini*

Quite common, particularly north of Marshalltown.

7. Woodchuck. *Marmota monax monax*

Quite common along Iowa river and Linn creek.

8. House Mouse. *Mus musculus*

An abundant pest.

9. Norway Rat. *Rattus norvegicus*

Common pest throughout the county.

10. Northern White-Footed Mouse. *Peromyscus leucopus noveboracensis*

Very common mouse. Eighty-nine were taken from about 226 pellets secured under a roost of four long-eared owls on April 3, 1913.

11. Meadow Mouse. *Microtus pennsylvanicus pennsylvanicus*

Every clover field has its quota of these mice, particularly on the river-bottom lands. Seventy skulls were taken from the long-eared owl pellets mentioned above.

12. Prairie Meadow Mouse. *Microtus ochrogaster ochrogaster*

Eighteen skulls of this mouse were identified in the long-eared owl pellets.

13. Muskrat. *Fiber zibethicus zibethicus*

Quite common in Iowa river and the Goose Ponds north of Marshalltown.

14. Pocket Gopher. *Geomys bursarius bursarius*

Common in all pasture lands and clover fields.

15. White-Tailed Jack Rabbit. *Lepus townsendi campanius*

Beginning to appear in the county. Old settlers told me that they had never seen it in the county until the last few years. I shot three during the fall of 1913 and saw the tracks of several more at various times.

16. Mearn's Cottontail. *Sylvilagus floridanus mearnsi*

Very common. I collected four on December 12, 1914, and shot others at various times.

17. Red Fox. *Vulpes fulvus fulvus*

I saw several skins in fur buyers' supplies that were taken along Linn creek in 1914. I was unable to get exact dates on these.

18. Coyote. *Canis latrans latrans*

An occasional one secured by trappers and brought in for bounty. I saw one alive on December 12, 1914, and learned of one den dug out in the spring of 1915.

19. Illinois Skunk. *Mephitis mephitis avia*

I saw many skins of a large skunk and identified them somewhat doubtfully as this subspecies. The large skunk was common although probably not over half so abundant as the smaller species.

20. Little Spotted Skunk. *Spilogale interrupta*

The little spotted skunk, or, as it is locally known, the "civet cat," is common. I collected one on November 22, 1914.

21. Mink. *Putorius vison lutreocephalus*

Quite common. Next to the muskrat and skunk the fur of the mink is the one most commonly turned in by the farmer boys from their winter trapping.

22. Weasel. *Putorius longicauda* subsp.

Weasels were occasionally seen but I was never able to secure one to determine the subspecies.

23. Raccoon. *Procyon lotor lotor*

Not common, though more abundant than many people suspect. I saw two killed by Mr. Henry Friese, on October 11 and October 18, 1914, respectively.

24. Short-tailed Shrew. *Blarina brevicauda brevicauda*

Five skulls of these shrews were taken from the long-eared owl pellets referred to under the various species of mice.

25. Least Shrew. *Cryptotis parva parva*

One skull of this species was found in the owl pellets.

26. Prairie Mole. *Scalopus aquaticus machrinus*

Common. One collected November 1, 1914, was identified as this subspecies by Dr. H. H. T. Jackson.

27. Red Bat. *Nycteris borealis borealis*

On June 20, 1915, a female red bat was brought to me by a high school boy. This bat had two young clinging to it. I kept it in a screened porch for two days, but it escaped.

28. Free-tailed Bat. *Nyctinomus depressus*

One caught alive on October 21, 1914, and recorded in Proceedings of the Biological Society of Washington, Vol. XXIX, p. 86, April 4, 1916.

BIRD BANDING AND INCIDENTAL STUDIES

DAYTON STONER

While the phenomena connected with bird migration have been studied for more than two thousand years much is yet to be learned of this most interesting and still more or less obscure characteristic of our "feathered bipeds." In attempting to throw some light upon their movements new methods have been devised and, in a degree, perfected. Until recently it has been the aim of ornithologists to study the migratory habits of *species* or even of larger zoological groups; but of late an effort has been made to study *individuals* of a species by marking the birds in some permanent manner so that they may be subsequently observed and their movements definitely recorded.

The latter method has consisted, for the most part, in attaching to birds either in the immature or adult stage a small, inscribed metal band the data on which are recorded in a central bureau or organization. Although bird banding itself is not a new thing, proper direction and control of these activities have been lacking. However, since May, 1920, the United States Biological Survey has assumed authority over the work and with this energetic and efficient branch of the Government service at the helm to rejuvenate the efforts of individuals and various cooperative agencies, a more definite and systematic plan of endeavor should produce valuable results. Numerous difficulties have beset the Survey in initiating this project, but it has succeeded in interesting up to this time approximately one hundred persons to whom have been issued about five thousand bands.

In securing birds for banding two methods have been followed, both of which have proved successful. One method consists in banding nestling birds just before they are able to fly, while in the second method dependence is placed upon a scheme of systematic trapping for securing adult birds. Either method may be indulged in with satisfactory results although when once started under favorable conditions many more birds may be secured in the same length of time by trapping than by seeking out nests containing young birds. It is absolutely essential to the success of the project that large numbers of birds be banded for, of the countless thousands of birds only a comparatively few fall into mans' hands; and every banded bird increases the chances of finding out something about that individual or the species to which it belongs just to that degree.

It is not the intention or plan of those who sponsor the banding of birds to lend encouragement to their promiscuous hunting and killing for the explicit purpose of recovering the bands. But every legitimate collector, field observer and sportsman should be made aware of the exploitations now being made in an endeavor to bring to light new facts, so that he may be on the lookout for banded birds. Whenever such a bird is found the number or, if the bird is dead, the band itself should be forwarded to the United States Biological Survey, Washington, D. C., along with whatever data may be obtained concerning the taking of the bird.

Now, while bird banding in itself is a valuable and laudable phase of ornithological endeavor numerous interesting and incidental features are bound to force themselves upon the attention of the investigator. During the summer of 1920 the writer spent the months of July and August at the University of Michigan Biological Station in northern Michigan. The Station is located on Douglas Lake which lies in the coniferous belt about seventeen miles from the Straits of Mackinac on the north, Lake Michigan on the west and Lake Huron on the east. Many favorable nesting sites for birds are offered and numbers of species that we in Iowa see only as migrants nest among the pines and aspens in more or less safety and seclusion.

Here, during a period of about six weeks, 115 birds representing twenty different species were banded. Of these, 106 were nestlings occupying thirty-nine nests, eight were young birds captured after leaving the nest and one was an adult.

And so, while looking for subjects to band and studying the inhabitants of nests before and after banding we were brought face to face with many interesting sidelights relating to the behavior and habits of certain birds which, under other circumstances, might have escaped us. It is on some of our findings in this field that I should now like to briefly direct my remarks. The order of presentation of the species herein included is based solely upon the order of sequence in the A. O. U. Check List.

Spotted Sandpiper. *Actitis macularia* (Linn.). As might be expected, spotted sandpipers are not uncommon in the region and during the first half of July young birds may be seen almost anywhere along the beaches. On July 10 a family of four young, apparently not more than two or three days old, was captured on the beach near camp. After a considerable chase the youngsters were assembled in a hat where they were kept temporarily confined while the process of banding occurred; during this time the female flew about calling continually and apparently in great distress. After the young were banded the hat was pinned so that the birds could not escape and then left upon the beach with its precious contents. The observers all having selected hiding places, the distracted female cautiously approached the place, *i.e.* the hat, from which the faint chirps of the young birds could be heard, finally coming to stand directly *on* the hat calling constantly but giving no indication to us that she was aware of the proximity of her family; later she scurried away again as if not certain of the place from which the call notes of the fledglings issued.

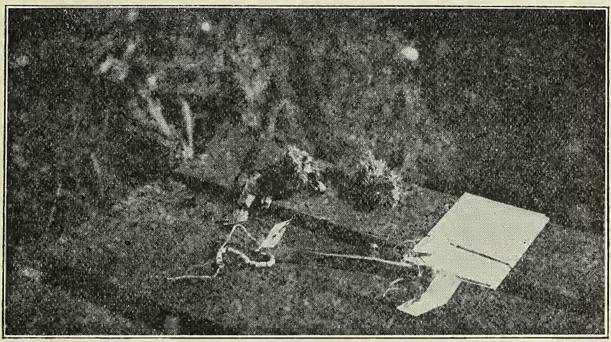

Fig. 27. Young Black-billed Cuckoos and bird banding paraphernalia.

Black-billed Cuckoo. *Coccyzus erythrophthalmus* (Wils.). The black-billed cuckoo is much the commoner species of the region and we were privileged to study the inhabitants of two nests. On July 14 a nest about three miles from the Station was visited. This nest was in a low balsam tree about four feet from the ground and at the side of a trail leading into a bog. It was a shallow, saucer-shaped platform composed of coarse twigs and lined with willow catkins, well protected from sun and wind. Upon our arrival the brooding female remained on the nest while the photographic apparatus was set up within three feet of her and several exposures were made. In the meantime the male repeatedly gave a series of low *koor - uck - uck - uck* alarm notes from a nearby tree. When the female was flushed the nest was found to contain two black young with conspicuous white feather tubes. I judged that the birds were about four days old.

The other nest of this species was discovered on July 26 at which time it contained three eggs. On August 2 the nest contained five eggs and one young about three days old. While we were photographing the nest and its contents and banding the nestling one of the eggs which was pipped began to crack open and with a little assistance from us the bird was soon out. The young bird seemed perfectly dry on issuing from the shell, little if any of the amniotic fluid remaining at this time. While these events were transpiring the parent birds remained in the vicinity very much excited, sometimes flying almost to our feet and all the time giving vent to the characteristic alarm notes. On August 13 the nest was again visited when it was found to have been abandoned along with three eggs. Probably two young had left the nest alive. This nest was about two feet from the ground in a low beech seedling which had sprung up in a burned-over area. It was more compactly built than the one above described and was almost completely concealed by the leaves of the seedling.

Belted Kingfisher. *Ceryle alcyon* (Linn.). One of the most interesting families of young birds that was banded consisted of six belted kingfishers. Their home was located in a sand bank on the east shore of Douglas Lake about six feet above the water-line and forty feet from the edge of the lake. The excavation, which was not more than two and one-half feet in length,

Fig. 28. Young Belted Kingfishers about ready to leave nest.

curved inward among the more or less exposed roots of a large white pine (*Pinus strobus*), its terminus where the birds rested being about twenty inches below the surface of the soil.

On digging down to the nest the six blinking, frowsy-headed youngsters, three males, and three females, all fully feathered, were exposed to the light. Contrary to what I had been led to expect from previous reading the nest was not a foul, ill-smelling place. There were no signs of dead fish or fish bones and only a very little excrement was found. The young birds were temporarily removed from their cool dark nest, admired, banded and photographed, during which latter process they posed as quietly and accommodatingly as the most exacting photographer could have desired. They showed no tendency to walk backward, a curious habit mentioned by some writers.

A few days previous to this experience, while on a field trip with my class, we had seen one of the parent birds, which was carrying a fish, alight in a tree near by. The bird probably becoming excited at the presence of about twenty observers dropped the fish and flew away. Upon examination this fish proved to be a brook trout (*Salvelinus fontinalis*).

Whippoorwill. *Antrostomus v. vociferus* (Wils.). The whippoorwill is a common bird of the region and during the height of the breeding season may be heard calling *vociferously* on all sides during the early evening and morning. On a number of occasions I have made counts of consecutive calls given by a single bird and these results only tend to increase our wonder at the remarkable vocal ability of their possessors. One count gave 294 consecutive calls with but three very short intervals; another count gave 396 calls with three very brief intervals during their utterance and another gave 446 calls with five brief intervals. The average number of consecutive calls diminished proportionately as the season advanced.

On July 13 a "nest" — simply a concavity on the dead leaves among the aspens — containing two eggs was discovered, and a week later two downy young were found at a point about two feet from the place in which the eggs formerly reposed. Although the young birds were able to flutter along the ground they chose not to do this on our approach but simply squatted and remained quiet, apparently depending upon the simulation of their coloration with that of their surroundings for protection. Indeed, so effective was this simulation that we almost trod upon the birds several times before we found them.

Cowbird. *Molothrus a. ater* (Bodd.). Still another item of ornithological interest that is likely to thrust itself upon the observer's attention in such a region as the one here discussed is the prevalence of the parasitic habit on the part of the cowbird and the general infliction of its presence, eggs and young upon numerous species of birds. Either the eggs or young of this polygamous and polyandrous outcast of the *Icteridae* were found in nests of *Vireosylva olivacea* on two occasions, *Hylocichla guttata pallasi* on two occasions and *Junco h. hyemalis* on one occasion. In this latter nest two cowbirds and one junco were waging the struggle for existence with the odds in favor of the former, which were larger, stronger and much more active than was the rightful occupant of the nest.

Cliff Swallow. *Petrochelidon l. lunifrons* (Say). Cliff swallows, along with barn swallows, commonly nest under the eaves of some of the buildings at Ingleside, a small resort on the north shore of the lake. In all, fourteen young of the former species, which occupied six nests, were banded between July 15 and August 6. These birds were in various stages of development at the time of banding. In one group of three nestlings banded on July 24, two bore dipterous larvae of some kind upon the soles of their feet; one of these birds carried two of the larvae which were about 8 mm. in length and fully gorged with blood. In no other birds examined during the summer was a similar condition observed.

Hermit Thrush. *Hylocichla guttata pallasi* (Cab.). On July

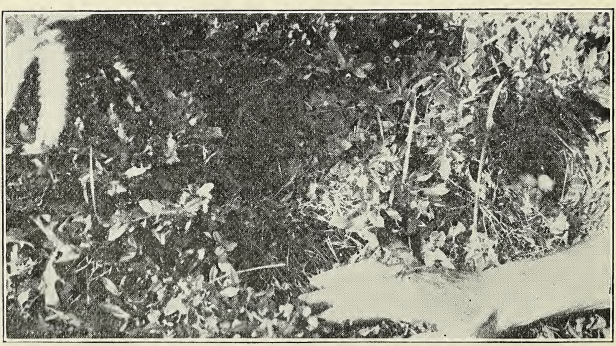

Fig. 29. Two nests of Hermit Thrush less than a foot apart; the occupied one contains three eggs of this species and one cowbird's egg.

13 a hermit thrush nest containing three eggs of this species and a cowbird's egg was discovered in a clump of blueberry bushes growing beneath a large pine tree. Upon cautiously approaching the nest and carefully laying aside the blueberry bushes another nest identical in construction, size and materials, but empty, was discovered less than a foot from the occupied nest. The unoccupied nest was in a good state of repair although it had apparently not been used that summer. Was the pair of hermit thrushes nesting in this blueberry clump the same pair which had nested here in 1919 or was this nesting site chosen at random by a pair which had not visited the place previously? The solution of this and similar questions, it is hoped, may be answered through results attained by bird banding.

In wandering about the woods in search of nests and young birds one is struck, after a time, by the fact that even here in a more or less isolated spot comparatively free from one of their greatest enemies — man — and in a place where the birds are subjected only to the attacks of their natural enemies, the mortality among young birds is surprisingly great. Two or three examples will serve to illustrate this point.

An ovenbird's nest, found on July 4 and containing four young not more than two days old was kept under observation from a blind until 4:00 P. M. of July 9. Twenty-four hours after the latter date the entire brood had totally disappeared. Snakes or red squirrels were accused by us for the depredation but without any direct evidence against them.

On another occasion the nest of a slate-colored junco containing three young was under observation from a blind for several days. On July 18, when the birds were four days old, the nest contained but a single juvenile. The next day Mr. H. C. Fortner found a garter snake (*Thamnophis sirtalis*) in the act of taking the last remaining member of the family. The reptile was promptly killed and the young bird was taken from its stomach. Farther on, in the intestinal tract, were the other two juncos in a partly digested condition. Perhaps, also, this snake had served as the host for our family of young ovenbirds whose nest was but a few feet from the junco's nest. Although two eggs still remained in the latter the adult birds did not again return to them.

A few days later while making observations on the activities of another junco family from a bird blind my attention and curiosity were aroused by a considerable commotion on the part of the parent birds. On looking out of the opening in my blind

I was unable to discover anything out of the ordinary. Apparently, however, the adult birds were becoming more disturbed than ever and on attempting to investigate the situation more closely by sticking my head out of the blind entrance I was met by a milk snake (*Lampropeltis t. triangulum*) which was crawling in to escape the angry pecking of the juncos. Immediately I disputed the occupancy of the blind with the snake to the destruction of the latter. When its stomach was examined no recognizable remains of birds were found. I feel certain, however, that if permitted to go its way unharmed it would have made away with at least some of the occupants of the nest. The snake measured 31½ inches in length.

Still another junco family of five was known to have lost two-fifths of its members before those remaining were large enough to leave the nest.

On other occasions the eggs and young of the hermit thrush, American redstart and chipping sparrow were found to have been molested but the actual commitment of the deviltry was not observed.

Although poisonous snakes do not abound in the region "garter snakes" are plentiful enough and no doubt take their toll of lives from the ground-nesting species of birds in particular.

One of the best ways of securing an estimate of the proportionate number of nesting birds in a locality such as the Douglas Lake region is by making a survey of the nesting pairs of birds therein. In seeking out nests containing young birds suitable for banding we were able to arrive at some fairly definite conclusions as to the most abundant species and those observations together with almost daily field work gave a checking up method that proved very satisfactory. This combination of records indicates relative abundance as follows:

1. *Bombycilla cedrorum*
2. *Spizella p. passerina*
3. *Junco h. hyemalis*
4. *Pooecetes g. gramineus*
5. *Melospiza m. melodia*
6. *Hylocichla guttata pallasi*
7. *Vireosylva olivacea*
8. *Planesticus m. migratorius*

In conclusion it may be said that interest and participation in bird banding is likely to lead to definite results not only in that work itself but in the accumulation of data which may be helpful in furthering our knowledge of birds and their habits. To date, but one of my banded birds has been recovered: a young robin, banded on July 21, 1920, at Douglas Lake was taken on January 21, 1921 in Perry county, Mississippi, fifty miles north of the Gulf of Mexico. Multiply such results many fold and the amount of information concerning various phases of the activities of robins will have become more widely disseminated. Numerous side lights will force themselves upon the attention of the student from time to time; and often the slight bits of encouragement thus afforded will prove a legitimate incentive for a continuation of interest which will result in intensive, thorough and exhaustive work in little developed though none the less productive fields.

State University of Iowa

ALCOHOLS AS FACTORS ALTERING FATIGUE PROCESSES IN FROG MUSCLE[1]

FRANCIS MARSH BALDWIN

INTRODUCTION

In a recent paper[2] experiments were cited which indicate that developing sea-urchin eggs when subjected to suitable concentrations of various liquid-soluble substances, i.e., the higher alcohols, show unmistakable rhythms of susceptibility and resistance according to the phase of physiological activity at the specific time of treatment. Such observations constitute additional evidence that a very intimate relation or correlation exists between the general physiological condition of the egg, and the physical state of its plasma-membrane. The present paper is a preliminary report of experiments conducted in the light of recent advances to analyze the effects of various concentrations of the alcohols upon the resulting fatigue curves of excised frog muscles so immersed. The bearing such a study has on the theoretical and practical aspects of responses is apparent when one recalls that in any protoplasmic system, an increased (sensitization) or decreased irritability or spontaneous activity (anaesthesia) may be brought about by the conditions of concentration, temperature, and the physiological state of the system.

In the case of substances, in proper concentrations, producing increased irritability, numerous examples might be cited both in plants and animals. It is well known that general nervous excitability is increased by weak doses of ether, alcohol and other active substances. Rhythmical activity such as that which takes place in cilia, or the heart beat, etc., is increased in weak solutions of alcohol and other narcotics. Carlson[3] has demonstrated that the nerve-cells controlling the heart beat of Limulus are induced to faster rhythmical action in weak solutions of alcohol, chloral hydrate, chlorotone and chloroform. In experiments by Tashiro and Adams[4] similar responses in excitability in the nerve and its output of carbon-dioxide were noted when it was treated with low concentrations of urethane and chloral hydrate. In muscle-nerve physiology, the phenomenon of "treppe" exibited by contracting muscle is probably due, as has been shown by Lee[5], to the stimulating action of small quantities of fatigue substances, which in higher concentrations decrease irritability. On the plant side numerous practical uses have been made of the fact that many depressant substances when administered in low concentration increase rate of growth. Thus ether has been used in "forcing" plant growth by those interested in commercial horticulture.

Other striking effects of narcosis on the side of oxygen consumption have been recorded in plants when they were treated with weak solutions of chloroform and ether. "Tashiro and Adams cite observations of Kosinski showing that respiration in yeast cells increased in presence of 0.5 per cent ether; 5 per cent reduces respiration one-half while 7 per cent almost stops it" [5] Rotation in plant cells has been observed within the protoplasm during the early stages of ether and chloroform narcosis, and it is recorded that the irritability of certain sensitive plants is heightened in the presence of traces of ether.

Loeb, Lillie, Torrey, Moore and others have observed striking behavior activities induced in various organisms when these were treated with the proper concentrations of certain anaesthetics. Thus Loeb was able to produce a positive heliotropic response in Daphniae when he had subjected it to solutions of alcohol and ether in strengths that vary from a third to a half of those required for anaesthesia. Lillie in experiments with the marine annelid larvae (Arenicola) found that he could change the behavior from a normally positive to a negative heliotropism in various weak anaesthetic substances.

On the other hand and opposite to sensitization, is the phenomenon of reversible decrease in irritability or responsiveness, which is anaesthesia, and the vital processes that are subject to such an arrest are numerous and varied, and may be brought about in a number of different ways, i. e., mechanical, thermal, electrical or chemical. In discussing the theory of anaesthesia, Lillie[8] lists a few of the vital processes so affected as follows: They include amoeboid movements; protoplasmic rotation in plant cells; all processes depending on response to stimulation, like muscular contraction and stimulation and conduction in nerve; automatic rhythmical activities like the heart beat or the motion of cilia or spermatazoa; cell-division; the artificial initiation of development in unfertilized eggs; various fermentative and oxidative processes; light-production, e. g., by luminous bacteria; typical metabolic processes like the assimilation of carbon dioxide by plants; growth processes in plants and animals, and developmental processes dependent on growth and cell division. It is of especial significance to note that processes depending upon growth and development are included in the list, and when anaesthesia is induced during proper progressive developmental stages, far-reaching consequences may result. Thus abnormalities of growth and development as well as changes in irritability may be produced under the influence of anaesthesia as Stockard[6] and McClendon[7] have shown in the production of cyclopia in developing fish eggs, and other developmental defects produced by alcohol in the case of mammals as later shown by Stockard.

It is beyond the scope and purpose of this brief introductory review of facts concerned with responses of the vital processes to attempt to discuss the cause or causes of observed phenomena, but it seems logical to infer that like manifestations of ordinary stimulation, they are in some way intimately dependent on surface-changes of the plasma-membrane. The question as to just how these surface-changes are effected is a critical one, and one that needs more careful research. A quotation from Lillie[8], on the theory of anaesthesia (p. 365) is relevant to the point just here. "An irritable element like a nerve-fiber or muscle-cell responds to a slight local electrical stimulation or mechanical impact; this response is apparently associated with a rapid and reversible increase of membrane-permeability; to this latter change the electrical variation is apparently due. It is this membrane-change, with the associated variation of electrical polarization, which appears to be the primary physiological event of stimulation; it spreads rapidly over the whole membrane, and the other consequences of stimulation (contraction, increased oxidation, etc.) follow upon this surface change. The question thus involves the whole problem of the physiology of stimulation.- - - - - - The whole process of stimulation depends on the local initiation of the excitation state, and on the rapid conduction of this state from the point of stimulation so as to affect the entire element. All of these processes depend on the physical and chemical condition of the membrane; hence altering this condition alters the whole stimulation process."

According to this conception the sensitivity of the membrane to changes of electrical polarization is its most characteristic peculiarity. The basis of this sensitivity remains to be determined. It would appear that the peculiar properties of the membrane depend upon its being a living structure, the seat of specific metabolism. That the characteristic semi-permeability depends upon this latter peculiarity is seen in the fact that the death-process, however induced, is always associated with a marked increase in general permeability and electrical conductivity of the cells. In other words, the normal semi-permeable condition — involving as it must a certain constancy in the composition and physical state of the surface film — is maintained only so long as the cell remains alive. This fact shows that semi-permeability, and the electrical polarization which is associated with this, are not simply static properties of the plasma-membrane, but are functions of specific metabolic activity — including probably oxidations in most cases — which maintains constant the physico-chemical characteristics of the surface-layer of protoplasm. In the irritable element this metabolism seems to be altered in a definite manner by changes in the electrical polarization of the membrane; and along with these chemical alterations go alterations of permeability, and secondarily of electrical polarization. These latter involve the production of local electrical circuits which traverse and hence stimulate the adjoining inactive portions of the irritable element. In this manner the state of excitation spreads and the whole element is stimulated. But this is the case provided only that the membrane retains its normal sensitivity to changes of electrical polarization; if it has previously been rendered resistant by an anaesthetic, no such effect follows; the element as a whole then shows itself irresponsive to stimulation.

With this brief discussion, we may proceed to the consideration of the mode of experimentation described.

METHODS AND APPARATUS

The experiments about to be described were performed intermittently between April and December of the past year, 1920, the frogs being obtained in five dozen lots from a supply house in Chicago, the batches consisting for the most part of the common or leopard frog, *Rana pipiens* Schreber, sometimes called *Rana virescens* Kalm. After making all due mechanical arrangements, the specimen was killed by pithing, the brain and spinal chord were destroyed, and the gastrochnemius muscle was removed and placed immediately in the glass cylinder of a Harvard type muscle warmer (J, Fig. 30), arranged and mounted in such a way as to allow easy manipulation in pouring solutions of desired strengths, and so connected to the inductorium (E) and the

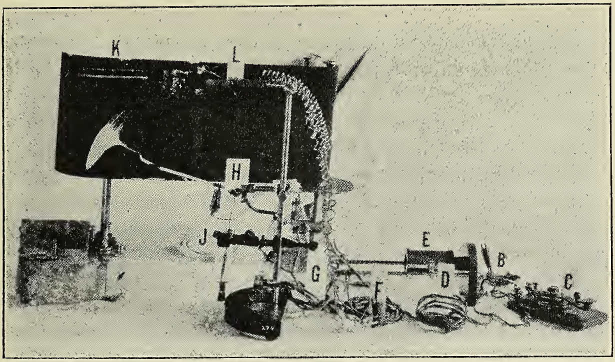

Fig. 30. Apparatus. Primary current enters B, passes to Key C and Inductorium E. Wires D activate signal for "make and break" on L; while F connects with chronometer beating half minutes. Wires G are induction to muscle in J and lever M. K is slowly revolving kymograph.

light muscle lever (H) as to allow the transcribing of a record on the kymograph (K) when the muscle was stimulated by the intermittent induction shocks. Immediately above the muscle lever was mounted a Deprez double electric signal marker (L), the upper marker being connected through wires (F) with a Harvard type chronometer beating off intervals of a half minute; the lower being connected through wires (D) with the primary circuit through a Harvard type vibrating interrupter beating seconds (a make and break during the second so that the muscle actually received through the inductorium two stimuli per second). The current used through wires (B) was from electric storage battery, type "D," cells maintained approximately at full charge (1.225 s.g.) delivering a voltage to the inductorium of about 2 per cell. Usually two cells were used to impel the induction coil of the interrupter, with one cell furnishing the current to the inductorium and the muscle which of course was connected to the inductorium through the terminals of the secondary coil. The secondary coil in all experiments was placed over the primary so that it was two cm. from its fully closed position, thus delivering to the muscle its maximal induction. After extended preliminary experimentation it was found that about the optimum mechanical advantage in terms of leverage for the muscle lever consisted of having the muscle attachment 8 mm. from the pivotal fulcrum opposed by a 30 gm. weight placed 14 mm. on the opposite side, the entire length of the writing arm being 150 mm. from the pivot. The kymograph used in recording was of the modified Harvard slow driving, long paper type, so provided with a fan that it made one revolution in about seventeen minutes. All records shown in the subjoined plates were made with the drum revolving at this uniform speed so that from this factor they are comparable.

During the experimentations care has been exercised to keep the various mechanical and thermal conditions as constant as possible; the temperature has not been allowed to fluctuate more than two degrees, at any time, usually the room temperature being kept as approximately 21°C. during all the experiments. The various concentrations of fluids used were made up in advance according to computed volumes per cent, and placed in small cork stoppered flasks of 150 cc. capacity so that at the time of experimentation they were approximately at room temperature. The manner of attachment of the muscle to the electrodes was carefully observed, and consisted of inserting the needle in the tendon achilles just at the junction of the fascia of the numerous muscle bundles for the lower contact; the upper end of the muscle being made secure by piercing the tendonous fascia at the knee joint between the distal end of the femur and the proximal end of the tibia. This precaution to make secure the electrodes was found to be imperative since otherwise the inertia of the falling weight on the writing lever opposing the muscle would invariably alter the elasticity of the muscle and complicate the curves, especially in the initial excursions of the lever.

By closing the short circuit bar on the key, the interrupter in the primary circuit activates [5] intermittently the signal magnet and at the same time sends the make and break shocks to the muscle through the inductorium. It is assumed that by keeping constant the relative positions of the primary and the secondary coils the resulting successive induced shocks which reach the muscle will be approximately of the same strength throughout any series of experiments. This factor, of course, is a very important one since the responses of skeletal muscles when applied with gradations of current are markedly affected in a number of its phases, especially fatigue, as has been recently shown by Pratt[9]. Assuming the factors just mentioned to be fairly constant throughout the series of experiments to be described, there is yet another variable not easily controlled, that of metabolic variability in the individual muscles. Equality in size and weight of the experimental muscles has been the only available criterion on this point. From comparative uniformity of the resulting curves obtained on repeated trials it would seem that this criterion could be relied upon within the limits of experimental procedure.

The alcohols used throughout the experiments were obtained from different sources; the methyl, ethyl and n-butyl were redistilled in the organic laboratory here at the college; the n-propyl was obtained from Merck; n-amyl, nonyl, decyl were obtained from the Eastman Kodak Laboratories. The last two named are put on the market as "technical" and were not used in this series of experiments. The secondary octyl was purified by the Eastman Kodak Company while its isomere capryl was "practical" and was redistilled here in the organic laboratory. Eastman's "technical" heptyl alcohol was used but for the most part records with this alcohol were unsatisfactory, probably because of its oily nature.

EXPERIMENTATION

Ranges in suitable concentrations of the alcohols vary widely according to the specifically desired physiological result. For example, Overton in his study of narcosis of tadpoles found the range to lie between 0.57 mols per L. for methyl to .0004 mols per L. for octyl. Contrasted to these concentrations are observations by Führer and Neubauer in producing Haemolysis where the range varied from 7.34 mols per L. for methyl, to .004 for octyl, and Vernon's range in the destruction of indophenol oxidase was even higher in the first four members of the series that he tried, being 10.5 to 14 mols per L. for methyl to .032 to 0.9 mols for butyl. These last figures correspond very closely to those found to apply to isocapillary solutions, e. g., from 14.0 mols per L. for methyl to 0.14 mols for amyl. On this basis it was necessary to compute ranges of concentrations over rather wide limits, and to select therefrom those concentrations that promised to produce the desired physiological effects, i. e., bearing in mind that solutions of strengths above the optimum concentration would likely be too toxic and would result in depression or inhibition (Anaesthesia) of the muscular response, and on the other hand those below would probably have a stimulating (sensitization) effect.

After making a number of preliminary observations the concentrations of the alcohols, volumes per cent, were selected as given in the following table:

TABLE I.

Alcohols	Concentrations of Alcohols (Vol. Per Cent)				
	Volume Per Cent	Volume Per Cent	Volume Per Cent	Volume Per Cent	Volume Per Cent
Methyl	Strong	50	29.1	20.8	12.4
Ethyl	95	50	17.2	9.1	7.4
N-Propyl	Strong	Saturated	13.3	5.9	3.7
N-Butyl	Strong	Saturated	4.7	3.4	1.7
N-Amyl	Strong	Saturated	1.1	0.5	0.2
Heptyl	Strong	Saturated	1.6	0.7	.04
S-Octyl	Strong	Saturated	0.62	0.29	0.15
Capryl	Strong	Saturated	0.50	0.15	0.05

The alcohols were diluted with distilled water. Under the conditions of experiments the muscles when immersed in physiological salt solution gave the typical initial contracture (treppe) phase for four or five strokes of the lever, followed by a decided relaxation phase longer in duration during which time an increased responsiveness was apparent. The second contracture phase develops regularly after the space of about half a minute, and the muscle shortens in such a way as to show a fall in the general contour of the top of the curve, accompanied by a gradual rise in the lower portion of the record. A typical record of this kind is shown in figure 12 of plate II. A similar series of phases occurs when the muscle is stimulated in air, but there being in this case no impediment in resistance to overcome by the muscle in its contraction the resulting curve is comparatively larger as is shown in figure 6. The superimposed lighter curve in this case results from the "make shocks" while the larger and darker area is caused by the more intense "break shocks". The mean time necessary to fatigue a muscle either in physiological salt solution or in air was found to be about four minutes, as recorded by the chronometer beating half minutes, basing the calculation arbitrarily upon the point at which the lower margin of the second contracture phase begins its final descent.

Methyl alcohol. — Strong methyl alcohol is markedly stimulating during the first few induced contractions (perhaps a dozen strokes of the lever), but its toxic effect is immediately noticeable and the progress of the second contracture is rapidly completed, the whole taking place in less than two minutes. A typical curve using this alcohol is shown in figure 1.

Methyl alcohol in strength of 50 vol. per cent, (Fig. 2) produces a rather uniform curve. The initial contracture phase is noticeably lacking, with an accompanying relaxation phase apparent as indicated by a drop in the excursion of the writing point. The second contracture phase is similar in form and duration to that produced by alcohol of great strength, fatigue resulting in this case in about one and three-quarters minutes.

Alcohol of 29.1 vol. per cent, as typically shown in figure 3, is decidedly stimulating during the initial contractions, but produces rapid fatigue once the secondary contracture phase is entered upon, the fatigue process lasting only one and one-half minutes.

Of all the concentrations tried with this alcohol it would seem from the records obtained that 20.8 vol. per cent gives the best combination of initial stimulation followed by rapid fatigue indicating toxicity, and alcohol of approximately this concentration may perhaps be considered as about on the border, possessing favorable penetrating qualities. The muscle reached its final contracture phase in about two and a quarter minutes and produced an interesting curve as shown in figure 4.

Methyl alcohol of 12.4 vol. per cent is obviously below optimum concentration to produce rapid fatigue. It, like the higher grades of this alcohol, stimulates noticeably during the initial contractions, but this character soon becomes masked, and the succeeding contractions proceed to assume contracture proportions. A typical curve produced by muscles thus subjected is shown in figure 5, and from comparison is similar to one produced in normal salt solution (Fig. 12).

Ethyl alcohol. — Strong ethyl alcohol has a surprising stimulating effect upon muscles undergoing the fatigue process, so that the onset of the second contracture phase is very slow and remarkably gradual. The treppe effect brought about is perhaps more conspicuous here than in any other cases tried. Once the final contracture phase is produced, however, it is maintained for a long time with scarcely any apparent decline. Muscles in this strength fatigue quite as slowly as those submitted to physiological salt solution. Figure 7 shows a typical record obtained with strong ethyl alcohol. There is little initial relaxation apparent such as develops in concentrations of lower strengths.

Ethyl alcohol of 50 vol. per cent, is remarkable in that it produces a sustained relaxation phase of uniform responsiveness as is evidenced by the plateau form of the record, (Fig. 8), accompanied by a rather uniform base line. Once the fatigue is brought about, the second contraction phase appears rapidly as evidenced by the uniform ascent of the lower margin of the described curve. Contracture, however, is not prolonged as in strong alcohol, but begins immediately and is regular as in the case of normal fatigue.

The relative effects of subjecting muscles to the three lower concentrations of ethyl alcohol, namely 17.2, 9.1 and 7.4 vol. per cent may best be seen by referring to typical curves shown respectively in figures 9, 10 and 11. That an increase in sensitization is caused by a decrease in concentration is strikingly apparent here. The highest of these three concentrations brings about almost immediately the onset of secondary contracture, so that the upper margin of the curve drops regularly while the lower margin has an accompanying uniform rapid rise, the whole fatigue process taking only one and a half minutes to complete. Contrasted to this type of curve are those of lower concentrations, where the secondary contracture phase is gradually induced and maintained at a relatively higher and more uniformly regular level. In both of these the time necessary to fatigue is better than two and one-half minutes, and the increased responsiveness of the muscle is evidenced by the increased height of the recording lever. Once initiated, the decline in the secondary relaxation is rapid in all three cases which is in marked contrast to curves produced by practically all concentrations of propyl or butyl alcohols (see Figs. 13 to 19, inclusive) or in the case of strong methyl and ethyl alcohols (Figs. 1 and 7). This point, it would seem, is an important one in the analysis, since it implies that once the stimulating effect has run its course, changes are brought about in the muscle which in turn now reverse the process and something akin to anaesthesia ensues so that the relaxation is induced as rapidly as contracture was at first effected.

Propyl alcohol. — Propyl alcohol in all ranges of concentrations except one (3.7 vol. per cent. Fig. 17), gives striking and characteristic fatigue curves as may be seen by referring to figures 13 to 17. On being immersed, the muscle immediately begins to shorten and this is accompanied by an increased sensitization in most of the concentrations tried. This tendency to immediate shortening is especially noticeable in strong and saturated solutions, but is more or less conspicuous in the lower concentrations. In strong propyl alcohol there is only a suggestion of the treppe, the noticeable phase being the uniform secondary contracture which is maintained at a relatively high level (Fig. 13). Saturated propyl forms a plateau with accompanying contracture (Fig. 14) with maintained high contracture phase. In strengths 13.3 and 5.9 vol. per cent the resulting curves are very similar to one another as shown in figures 15 and 16, respectively. In the lowest concentration tried, 3.7 vol. per cent, the muscle fatigues uniformly and quickly, but after the completion of the second contraction phase it goes into relaxation rapidly so that the resulting curve (Fig. 17) is in this respect exceptional to the other concentrations of this alcohol, but comparable to the lower strengths of ethyl alcohol noted above.

Butyl alcohol. — Strong and saturated solutions of this alcohol give curves (Figs. 18 and 19, Pl. III) which are typical and which are comparable with similar strengths of propyl alcohol just described. Contracture starts almost immediately on the muscle's being stimulated and is maintained at a remarkably uniform rate with almost no relaxation phase at the end of the fatigue cycle. The three solutions of weaker strength of this alcohol which were tried, namely, 4.7 (Fig. 22), 3.4 (Fig. 21) and 1.7 (Fig. 20) vol. per cent, gave typical curves similar to each other and to the weakest concentrations of ethyl and propyl alcohols. This would seem to indicate that the differences in range as computed were not sufficient to give differences in effective physiological responses which were sufficient to analyze. All tend to have a definite comparable initial relaxation phase as indicated by the drop in the writing point in the early progress of the curve, and all on the completion of the second contracture phase have a rather rapid onset of secondary relaxation as indicated by the abrupt descent at the terminal portion of the curves. It is very evident, too, that these concentrations have an exhaustive stimulating effect since fatigue once started proceeds rapidly, and that in this respect they are more potent than the three low grades of either methyl and ethyl alcohols and even more so than comparable toxic strengths of its predecessor propyl alcohol.

Amyl alcohol. — In strong and saturated concentrations amyl alcohol gives curves similar to those of comparable strengths of both propyl and butyl alcohols and decidedly in contrast to comparable strengths of methyl and ethyl alcohols. With strong amyl alcohol the first contracture phase is produced immediately when the muscle is stimulated as is shown in figure 23, and proceeds gradually to produce the secondary contracture (see Fig. 13 for comparison with propyl alcohol). The plateau of secondary contracture is with this alcohol more pronounced and extensive than is the case with propyl or butyl alcohols. The three lower concentrations used, 1.1, 0.5 and 0.2 vol. per cent, strange to say, give curves (Figs. 25, 26 and 27, respectively) which in all details more closely resemble the three comparable strengths of methyl alcohol than any other concentrations of its predecessors (see Figs. 3, 4 and 5 in comparison).

Hexyl and Heptyl alcohols. — No hexyl alcohol was available at the time of experimentation so that no records were obtained. Heptyl alcohol was at hand and its effects on fatigue in different concentrations were explored somewhat but due to incompleteness of records no comparisons of value can at this time be made.

Octyl alcohol. — Two isomeric solutions of this alcohol were tried, a secondary octyl from a purification process of the Eastman Kodak Company, and a so-called capryl alcohol from the same source, redistilled here. Little difference physiologically could be seen in using either in similar saturated solutions. Both give curves (Figs. 28 and 29) in strong and saturated solutions which are remarkable in their similarity, not to their immediate predecessors of equal strengths, but to ethyl alcohol. The three lower concentrations, however, give curves (Figs. 30, 31 and 32) which are fairly comparable to similar concentrations of butyl alcohol, with perhaps a less marked similarity to the weakest strength of ethyl and propyl alcohols. These considerations when taken together with certain other data seem to point to the fact that octyl alcohol in various concentrations does not have as striking penetrating qualities as butyl, propyl or amyl alcohols. From incomplete records obtained in use of heptyl it would seem that this alcohol also is in a similar category.

SUMMARY

By making use of a proper laboratory apparatus herein described in which experimental conditions may be kept reasonably constant, records were obtained in the development of fatigue in the gastrochnemius muscle of the frog while it was being subjected during its stimulation to certain computed concentrations of various alcohols.

The ranges of concentration explored may be briefly tabulated; strong and saturated solutions of methyl, ethyl, propyl, butyl, amyl, heptyl, octyl and capryl, with computed graduations in three series of each, varying from 29.1 methyl, to 0.62 vol. per cent octyl; 20.8 vol. per cent methyl, to 0.29 vol. per cent octyl; and 12.4 methyl to 0.15 vol. per cent octyl, respectively.

On comparative analysis of the various phases of these curves certain inferences can be drawn as to penetration of the different alcoholic concentrations used and their resulting effects on the

muscle, both as to stimulation or sensitization and inhibition or anaesthetic effects. Strong concentrations in general give remarkably uniform modifications in phases of contraction, especially in producing immediate contracture which merges without interruption into irreversible secondary contracture. Certain weak solutions in general are markedly stimulating as is evidenced by an initial and somewhat prolonged relaxation phase followed by a reversible contracture phase which is very pronounced. Certain predictable differences were obtained in concentrations between the two extremes.

The evidence presented would seem to indicate that when they are undergoing the process of fatigue muscles are qualitatively susceptible to differences in concentration of the medium with which they are surrounded. This implies that an intimate relation exists between the physical state of the muscular envelop (plasma-membrane) and the changing physiological conditions within.

REFERENCES

1. From the Physiological Laboratory, Dept. of Zoology and Entomology, Iowa State College, Ames, Iowa.
2. Baldwin, F. M., Biol. Bull., Vol. 38, pp. 123-140, 1920.
3. Carlson, A. J., Am. Journ. Physiol., Vol. 17, p. 182, 1906.
4. Tashiro and Adams, Internat. Zeitsch. f. Physik-Chem. Biol., Vol. 1, p. 450.
5. Lee, F. S., Am. Journ. Physiol., Vol. 18, p. 267, 1907.
6. Stockard, C. R., Am. Journ. Anat., Vol. 10, p. 369, 1910.
7. McClendon, Am. Journ. Physiol., Vol. 29, p. 289, 1912.
8. Lillie, R. S., Biol. Bull., Vol. 30, No. 5, 1916.
9. Pratt, F. H., Am. Journ. Physiol., Vol. 44, No. 4, p 530, 1917.

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PLATE II.

Explanation of Figures.

1. Typical fatigue curve resulting from stimulation of muscle immersed in strong methyl alcohol. Note the initial relaxation phase is almost lacking, and the temporary stimulating effect as evidenced by the height of the first few contractions.

2. Fatique curve of muscle immersed in 50 vol. per cent methyl alcohol. The early relaxation phase is here beginning to be conspicuous and is somewhat prolonged.

3. Typical curve when immersed in 29.1 vol. per cent methyl alcohol. Relaxation phase more pronounced, conspicuous treppe, but rather rapid onset of secondary contracture.

4. Curve resulting on immersion in 20.8 vol. per cent methyl alcohol. This concentration perhaps may be regarded as lying in a relative range of concentration where phases are well balanced in modification. A rather prolonged initial relaxation with long constant strokes, a uniform secondary contracture terminating in a reversible decline towards the end.

5. Curve resulting from immersion in the weakest methyl alcohol used, 12.4 vol. per cent. Somewhat stimulating as evidenced by the early relaxation phase, the height of the excursions and the duration of upper margin of the plateau of secondary contracture.

6. Comparative curve resulting from stimulating muscle in air. Note the height of excursions, the initial relaxation phase, and the gradual and uniform development of secondary contracture. The whiter area inside is caused by the less intense "make" shocks.

7. Typical strong ethyl alcohol curve. Practically no initial relaxation phase, gradual onset of secondary contraction, a conspicuous treppe, and a sustained contracture plateau.

8. Typical curve using 50 vol. per cent ethyl alcohol. Phases in marked contrast to preceding, initial relaxation, rapidly developing secondary with maintained plateau becoming reversible.

9. Typical curve using 17.2 vol. per cent ethyl alcohol. Stimulating with modified toxic effect; note the rather prolonged initial relaxation followed by rapidly developing secondary with sharply descending plateau.

10. Typical curve using 9.1 vol. per cent ethyl alcohol. Stimulating with more slowly toxic effect. Gradual onset of secondary contracture and maintenance of plateau and reversible decline.

11. Typical curve using 7.4 vol. per cent ethyl alcohol. Not greatly different from preceding.

12. Typical curve obtained under same experimental conditions as all the others but in physiol-salt solution, 0.7 vol. per cent. Note the initial relaxation phase accompanied by treppe at the top, the gradual onset of secondary contracture, and a slowly reversible decline, with maintained gradual inclined plateau.

13. Characteristic curve resulting from immersion in strong propyl alcohol. Primary contracture very evident with no reversal to relaxation whatsoever, immediate onset of secondary contracture, terminating in irreversible plateau.

14. Typical curve using saturated solution of propyl alcohol. A slight assumption of initial relaxation, no treppe, uniform plateau almost irreversible.

15, 16, 17. Typical curves using 13.5, 5.9 and 3.7 vol. per cent propyl alcohol. First two maintaining almost an irreversible plateau, the last showing a rapid decline.

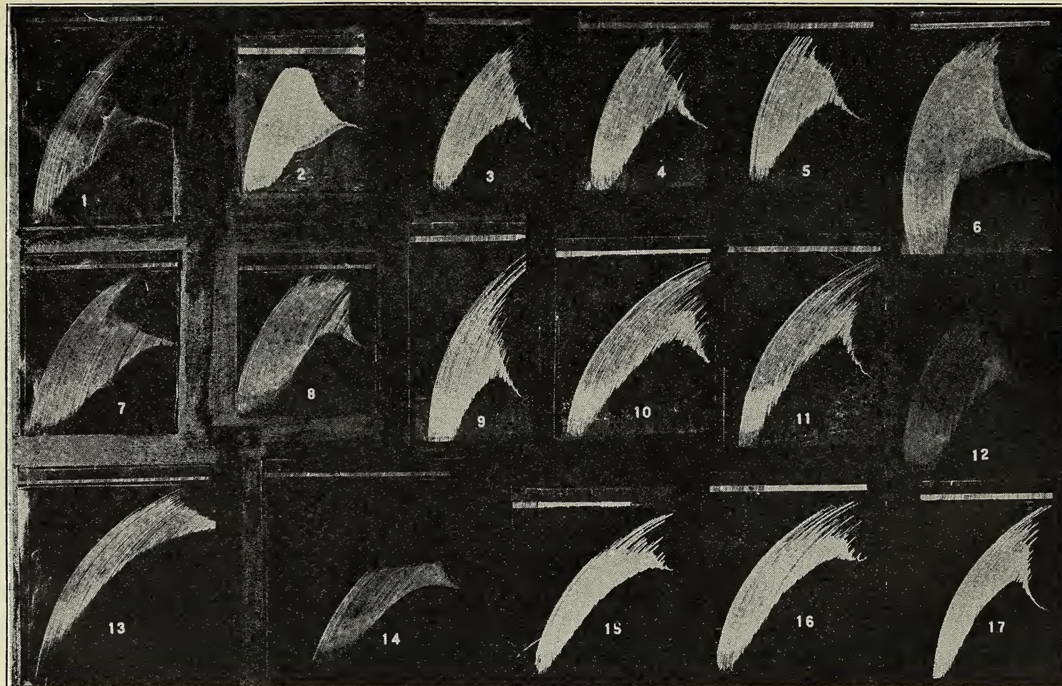
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PLATE III.

18. Typical curve in strong butyl alcohol. Practical absence of initial relaxation phase, rapid onset of secondary contracture with maintained final plateau.

19. A suggestion of initial relaxation phase in saturated solution of butyl alcohol, with maintained horizontal plateau which is slowly reversible.

20, 21, 22. Curves resulting on immersion in 1.7, 3.4 and 4.7 vol. per cent butyl alcohol, respectively. By a mistake the order in strengths was reversed in the labeling. 22 is the strongest (4.7), 20 the weakest (1.7). Characteristic in reversible decline.

23. Typical curve in strong amyl. Note similar contours to those obtained with propyl and butyl alcohols of equal strength.

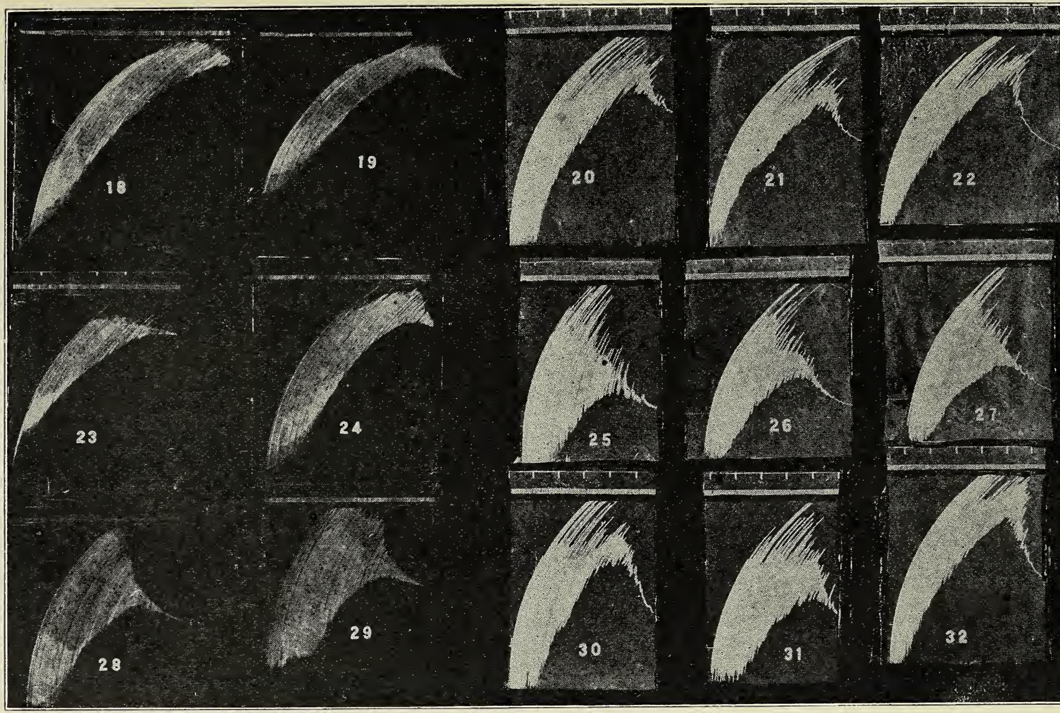
24. Typical curve obtained in saturated solution of amyl alcohol. Comparatively similar to equivalent strength of propyl and butyl alcohols.

25, 26, 27. Curves produced in solutions of 1.1, 0.5 and 0.2 vol. per cent amyl alcohol, respectively. Characteristically different from those of similar strengths of propyl and butyl, and more closely resembling those of weak solution of methyl alcohol (3, 4 and 5).

28. Curve resulting from immersion in secondary octyl alcohol, and in sharp contrast to those in strong solutions of its predecessors, propyl, butyl and amyl alcohols. Notice an initial relaxation phase whic nowhere else in curves of strong alcohols, and almost as extensive as that produced in salt solution (12), in fact, in all its details it is almost a duplication of curves produced in salt solution.

29. Saturated solution of secondary octyl alcohol. It contrasts sharply with curves obtained from similar concentrations of propyl, butyl and amyl alcohols, and its nearest simile is that produced by comparable strength of ethyl alcohol (8).

30, 31 and 32. Curves of secondary octyl alcohol of weak strengths, 0.62, 0.29 and 0.15 vol. per cent, respectively. These, as can readily be seen, are easily comparable to those obtained from similar strengths of butyl, and to a less degree of propyl alcohols.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ANALYSIS OF CERTAIN SMOOTH MUSCLE RESPONSES

B. M. HARRISON AND FRANCIS M. BALDWIN

The fact that smooth muscles differ fundamentally in their structure from the cross-striated form, and that they possess distinctive physiological properties, especially in their toxicity, rhythm and rate of response, has made them the object of rather extended investigations. It is not necessary here to review extensively the literature dealing with the various points of attack contributory to an understanding of the responses of such elements. Budington[1] in his paper on annelid muscles brings together an extended bibliography summarizing the work in this field prior to 1902, especially that done on muscles of the invertebrates. Inasmuch as his work was with the muscles of the body wall of the earthworm which is one type concerned in the present paper, reference to his results will be made later. Subsequently such workers as Bethe[2] (1903), Grützner[3] (1904), von Uexküll[4] (1905-1908), Meigs[5] (1908, 1909, 1912), Snyder[6] (1914), Satani[7] (1919) and many others have contributed much to our knowledge of smooth muscle responses, from both the theoretical and the practical sides. The present paper is a preliminary report of an attempt to analyze the responses of smooth muscles when subjected to different conditions, and especially when immersed in solutions of computed strengths of the alcohols, and continues in a comparative way a study reported recently by one of us (Baldwin[8]) using the voluntary gastrocnemius muscle of the frog.

APPARATUS AND METHOD

The apparatus used was adapted from that described in former experiments[8] and differed chiefly in an adjustable modified light muscle lever mounted in such a way as to subtend the muscle within the glass chamber into which fluids could be easily introduced and removed.* As a check on time of stimulation and dur-

* The muscle lever used in these experiments was made of very thin aluminum sheet, 31 cms. long and mounted upon very delicate knife blades as a fulcrum. Delicate knife blades also were mounted at the point of attachment of the muscle and the ratio was so computed that an approximal balance was effected. The ratio of magnification was 1:30, and the mechanical impediments were reduced to a minimum. The

ation of the experiment, a double Deprez signal was used, one magnet activated by the primary circuit recording the stimulus applied, and the other connected with the Harvard type chronometer beating half minutes. As a check on the variation in temperature throughout the series of experiments, a thermometer was mounted within a glass chamber. From extended preliminary observations it was found that the optimum strength of current was about six volts (three fully charged storage cells of about two volts each). The secondary coil of the inductorium was used in its fully closed position in practically all of the experiments herein described, and as a check on the effect of resistance, various lengths of calibrated German silver wire of a Harvard long typed rheocord were used. The effect of such resistance when thrown into the secondary circuit will be discussed below. In certain experiments an automatic circuit breaker was used, mounted and mechanically impelled by a Harvard type kymograph mechanism.* All records were obtained upon a slowly revolving kymograph (one revolution in sixty minutes) so that from this factor they are comparable. The factor of sluggishness in responses in most muscles used made it necessary to use for the most part the tetanizing current, and for this the inductorium was set as an interrupter, the number or rate of the stimuli being automatically regulated by the contact device on the kymograph just referred to. In most of the experiments, not less than thirty-six nor more than forty double stimuli were employed, any exceptions to this rate being stipulated on the records in each case. Different muscles of various animals were used in the course of the experiments; i.e., tissue of the regions of the esophagus, stomach, intestine and oviduct of the frog; regions of the esophagus and stomach of the turtle; the circular muscles of the body wall and the intestinal tract of the earthworm in certain regions

fulcrum of the lever was mounted in a way that by turning a fine threaded screw, adjustments could be made for the point to compensate for "stretch" of the muscle or other necessities, and could if desired be maintained at a level of a "base-line." Adjustment could be made easily and quickly without interfering with other manipulations. The glass chamber was provided with a stoppered outlet at its base so that fluids could be drained quickly by pressing a stop-cock. A funnel mounted just above the mouth of the tube facilitated pouring the liquids in, and was so inclined that fluids poured would strike the sides of the tube without "splash," and would gradually submerge the muscle. In each case after alcohol was used the funnel and glass chamber were rinsed out with distilled water.

* This modification consisted chiefly of mounting securely the binding posts of a Zimmerman contact breaker upon the top plate of the kymograph, and mounting a circular-like breaker tract of heavy copper wire upon the revolving spindle. By trials, the time of contact could be determined and accurately calibrated against a standard chronometer.

back of the clitellum. The frogs upon which a large series of experiments were made were obtained from The Anglers Company, Chicago, and were placed in a tank with water where the temperature was rather constant, varying only slightly from room temperature (around 70° F.). At the time of experiment they were pithed and the spinal chord destroyed, a portion of the region desired removed and placed usually in 0.7 per cent salt solution. Great care was observed in removal of the part desired so as to standardize as far as possible any differences in response which might conceivably be attributed to differences in extent and morphological position of the part. In the removal of the esophagus, the cutting was so done as to obtain a portion about a centimeter in length. The first incision was made just anterior to the branch of the artery supplying the posterior portion, and another cut was made just posterior to the point of immergence of the tube into the abdominal cavity. The same care was exercised in removing portions of the stomach, since portions close to either end exhibited rhythmical responses probably due to their respective sphincter muscles. Usually rings of about one cm. in length from the central area were used, although mention of the behavior of other areas will be made later.

When portions of the body wall of the earthworm were used, the procedure in preparation was as follows: Specimens of various species were obtained on the campus and brought into and kept in the laboratory in a jar of moist earth, the room being kept at about 70° F. A specimen at the proper time was removed from the jar, washed in tap water to remove dirt and grit and placed on a moistened cork pad. In a short time it was quiet enough to count under a dissecting lens ten somites which in all cases constituted the desired ring of tissue. The first ten somites were taken just in back of the clitellum, and then successive rings of ten were cut as needed subsequently, the posterior portion of the worm being placed in the meantime in tap water just sufficient to keep it moist, but not submerge it.

A technique of mounting the tissues in question was developed which was found to be very important to the success of the resulting experimentation, and a word needs to be said just here. Two equilateral triangles (1 cm. a side) of fine (about No. 24) copper wire, were made in such a way as to form a sort of safety-pin, with a hook-like clasp at one end. By running the free end of each triangle through the ring of tissue and clasping, the triangles made an admirable support for the tissue, and in turn served as contact terminals for the electrical connections, one through the muscle lever at the top, the other through the stopper in the glass chamber at the bottom. Thus the preparation when mounted had a mitotic spindle-like appearance.

EXPERIMENTAL

It was at first necessary to procure what may be called typical records under the conditions mentioned. To this end the strength of stimulus was the only variable allowed to enter, and we were able after considerable experimentation to predict just what effect this factor would have on the form of resulting curves in the various tissues explored. In general the height of the contraction, its duration and the phase of relaxation were prolonged in relative proportions (within limits) to the number and rate of stimuli.

This fact is very clearly illustrated by comparing two typical curves of the anterior portion of the frog stomach where in one case the stimulus was a tetanizing current * of 2½ seconds duration (Fig. 1, Pl. V) and in the other of about 5 seconds duration (Fig. 2). The form of the curves differs only slightly in the relaxation phase of the second. Other tissues tried gave similar differences when this variable entered although the types of the curves were uniform according to the tissue used. This is similar to the results obtained by Budington[3] in his work on responses of earth worm muscles. On the other hand by keeping the strength and rate of stimulus constant, uniform repetitions could be made at will provided, of course, a standard interval of time was allowed to elapse between them to compensate for the fatigue factor. This is very characteristically shown in the curves of figure 6, which were obtained by using the middle of the frog esophagus, a ten minute interval being allowed between the two curves here shown. In experiments with frog muscles from regions of the alimentary tract where rhythmical contractions are frequently encountered, it was found best to allow an interval of ten to twenty minutes after mounting before stimulation, so that these contractions could gradually pass off. During this interval the rhythmical responses gradually become less and less marked as shown in figure 5. If the muscle be stimulated before quiescence is reached, and sometimes even after this state, the rhythm appears again on

* The rate of tetanizing current used was arbitrarily set at about thirty-eight to forty double vibrations per second in this and subsequent experiments.

the relaxation phase of the response, as is typically shown in figure 8. In posterior sections of the frog stomach an accessory response frequently, one could almost say, invariably, could be initiated on the relaxation of the curve following stimulation. Just where on the relaxation phase this secondary response appears is variable, sometimes (Fig. 4A) it is near the base, and again it is near the top causing a "summation" as in figure 4B. At present we are not able to make satisfactory explanation of this phenomenon.

In the case of the effect of resistance on responses, Budington in his experiments with the earthworm muscles showed that resistance when introduced had a decided depressing effect. We find in the earthworm a similar condition, as figure 10 shows, that is, when various amounts of resistance are introduced, there is a marked variation in the height of contraction, this in general being proportional in decrease as resistance is increased. Incidentally, under the maximum amount of resistance tried (twenty meters of German silver wire) where the resulting response is relatively small, an introduction of 1.2 per cent ethyl alcohol for thirty seconds before stimulation with the same amount of resistance, resulted in a contraction approximately ten times greater. On being stimulated again, five minutes later, a second response could be obtained almost as great. So far as the general type of curve produced is concerned it is comparable to the others, hence we may interpret that the immediate effect is one of sensitization only. Using the frog esophagus and the intestine, relatively similar variations in the height of the curves were obtained respectively on introducing resistance and a resulting sensitization on being subjected to certain weak strengths of ethyl alcohol as shown in figures 7 and 9.

The diminution in height of responses of earthworm muscle due to fatigue and resistance factors is strikingly shown in figure 12 where alternately twenty meters of resistance, and no resistance were applied, followed finally by the application of 0.78 per cent ethyl alcohol as a sensitizer. The contrasts in heights here need no further discussion. Most of our work on the fatigue process was concerned with the experiments with the circular muscles of the earthworm body, and it is safe to say that like the voluntary muscle there is evident the treppe phenomenon wherein a gradual accumulation of sensitizations is noticeable, and that like the voluntary muscle the latency period is very short. In this respect it differs decidedly from that of the muscles of the frog esophagus. If care is taken to select the proper interval between stimuli, say about three minutes, the optimum height of the response is obtained between the fifth and the eighth strokes. Beyond this optimum height there is a steady decline, but this seems not be accompanied by marked changes in toxicity as is usually the case in voluntary muscles. Figures 24 and 25 are typical records of this sort. According to the methods used the variation in the amount and duration of the current is assumed to be negligible. When the fatigue process had run its course, solutions of ethyl alcohol of 0.5 volume and 0.25 volume per cent, respectively, were added before final stimulation. In each, unmistakable evidence of a resulting sensitization was apparent which in height practically equalled that of optimal activity just referred to. The total time necessary to completely fatigue a muscle under these conditions was found to vary greatly. In some cases as short a time as thirty minutes was sufficient, in others upwards of an hour was necessary, and in one exceptional case where the stimulation was timed automatically, the tissue retained its responsiveness to an incredible degree for several hours.

The fact that ethyl alcohol administered in certain concentrations at the end of the fatigue process altered markedly the responsiveness of the muscle, and other considerations led us to explore the qualitative aspect of the effects of this and other alcohols on normal responses when they were varied in concentration. Two alcohols have so far been tried, but the results obtained are very suggestive and compare favorably with certain results obtained in the case of the voluntary frog muscle.

ETHYL ALCOHOL ON FROG MUSCLE

Several series of experiments were made to test the effect of various concentrations of ethyl alcohol on the normal responses of the muscles of the frog esophagus, and because of the uniformity of results in all cases we are convinced that the records cited here are typical. The range in concentration in this exploration varied from 40 vol. per cent, the highest, to 1.56 vol. per cent, but we have selected as illustrative of the modifying influence, strengths which range from 12.5 vol. per cent to 1.56 vol. per cent as shown in figures 13 to 17, of plate VI, inclusive. About twenty minutes after proper mounting in salt solution as described elsewhere, the tissue was stimulated to obtain a so-called normal response. After the muscle had become relaxed and adjusted to the base line the salt solution was quickly drained and alcohol in proper concentration was added. After the muscle had been stimulated one minute later the effect of adding the alcohol was recorded in each case. The 12.5 vol. per cent concentration (Fig. 13) gives a form of curve which we interpret as rather toxic as evidenced by a maintained, prolonged relaxation phase, and the low comparable height of the curve when compared to the four succeeding records. As the concentration is lowered this factor apparently changes to one of sensitization, the contraction phase is increased in height and at the same time the relaxation interval is reduced as evidenced by the rapid decline of the record. A decided increase in sensitivity is evident between concentrations of 9.00 and 6.25 vols. per cent (Figs. 14 and 15) but this difference is not quite so noticeable in the two lower concentrations (Figs. 16 and 17).

ETHYL AND PROPYL ALCOHOLS ON THE EARTHWORM MUSCLES.

Several series of experiments were made with earthworm muscles using ethyl and propyl alcohols of various strengths, and both show decided graded qualitative responses according to concentration. In these experiments care was exercised to have the muscle in each case working at its best, that is between the fifth and eighth stroke, when the alcohol was added in order to have a basis of uniform comparison. Using ethyl alcohol, we have selected worm 57 as typical of a whole series and we represent two normal and the modified response due to various concentrations in each of the figures 27, 18, 19, 20, 21 and 22 of plate VII. These records were obtained from successive groups of ten somites beginning with the 3d back of the clitellum. In each case the 7th and 8th responses are shown as normal just previous to the addition of the alcohol. When 40 vols. per cent was added and subsequently stimulated (fig. 27), a response was obtained which in height is not more than one-quarter that of the previous normal. When 25 vols. per cent was added under precisely the same conditions, the response was just about one-half of the preceding normal, as shown in figure 18. When 10 vols. per cent was added (fig. 19) the response was just about equal in height to the preceding normal. Figure 20 clearly shows that when 2 vols. per cent was added the response outstrips the previous normal by nearly one-half its height, while a still weaker solution, 1.2 vols. per cent (fig. 21), almost doubles it. The weakest concentration, 0.5 vols. per cent, shows still an increased height of response above that of the normal, but when compared to the two preceding records it is very evident that the optimum of stimulating effect has been passed, and that solutions of weaker strengths will be too dilute, and would show diminution of physiological effects. Aside from the height of the response, there are other interesting features of the curves which seem equally indicative of modified activity. If we note especially the form of the relaxation phase of the curves it is clear that a modification has been made here also. It changes successively from a maintained plateau in the strong solutions (figs. 27, 18) to a concaved form resembling the normal in lower strengths (figs. 20 and 21). Another interesting fact is brought out by applying a second stimulus in alcohol. We were able to obtain practically no secondary response in 40 and 25 vols. per cent concentrations, but in the 10.0 vol. per cent and below we could restimulate and obtain a response which in each case was considerable and proportional to the height of the first. This fact, it seems to us, lends further proof as to the correctness of our interpretation.

The effect of various concentrations of propyl alcohol is shown typically in successive series of somites of earthworm 101, figures 28 to 31 inclusive. Carrying out the same procedure as just mentioned, this alcohol yields interesting comparative data. On applying 10 vols. per cent propyl, the normal response is cut to about one-fourth in height (fig. 28), which fact when compared with 40 vols. per cent ethyl (fig. 27) is of value, when it is recalled that the computed toxicity of one member of the aliphatic series of alcohols is between three and four times that of its immediate predecessors.[9] When the concentration is reduced to 5.0 vols. per cent, the resulting response as shown in figure 29 is increased to about one-half of the normal height. In concentration of 1.0 vol. per cent, the response is practically doubled (fig. 30) and dilution beyond this point results in a drop in height (fig. 31) exactly as described above in the case of ethyl alcohol. Comparable differences were here also shown in the form of relaxation phase of the responses throughout, as well as a corresponding ability to respond to restimulation. These similarities are strikingly shown on comparing figures 27 and 28; 20 and 29; 21 and 30; and 22 and 31.

REFERENCES

1. *Buddington, R. A.,* Amer. Journ. Physiol., vol. VII, pp. 155-179.
2. *Bethe, A.* Allgemeine Anat. u. Physiol. d. Nerven, p. 363, Leipzig, 1903.
3. *Grützner, P.,* Ergebnisse, d. Physiologie, Vol. III, pt. 2, 1904.
4. *von Ueckküll, J.,* Zeitschrift f. Biologie, p. 91, 1909.
5. *Meigs, E. B.,* Amer. Journ. Physiol., Vol. XXII, p. 477, 1908.
   Amer Journ. Physiol., Vol. XXIV, p. 1, 1909.
   Amer. Journ. Physiol., Vol. XXIX, p. 317, 1912.
6. *Snyder, C. D.,* Amer. Journ. Physiol. Vol. XXXV, p. 340, 1914.
7. *Satani, Y.,* Amer. Journ. Physiol., Vol. XLIX, p. 474, 1919.
8. *Baldwin, F. M.,* Reported at Iowa Academy of Science, April 1921. This volume, pp. 161 to 179.
9. *Lillie, R. S.,* Theory of Anaesthesia, Biol. Bull. Vol. XXX, pp. 332-333, 1916.

DEPARTMENT OF ZOOLOGY
IOWA STATE COLLEGE

PLATE IV.

Explanation of Apparatus.

1. Wire bringing current from storage batteries.
2. Wire of primary circuit to signal magnet at M.
3. Wire of secondary circuit to muscle in glass chamber C.
4. Wire extending from chronometer to time marker magnet M.

B. Lever arm marking base line.
C. Glass chamber containing muscle.
D. Stop cock, controlling liquid in glass chamber C.
H. Kimograph stand equipped with a modified Zimmerman contact breaker.
K. Kimograph.
I. Inductorium.
L. Writing lever to which muscle is attached.
M. Double Deprez signal magnet used for time and signal markers.
R. Rheocord.
T. Thermometer.

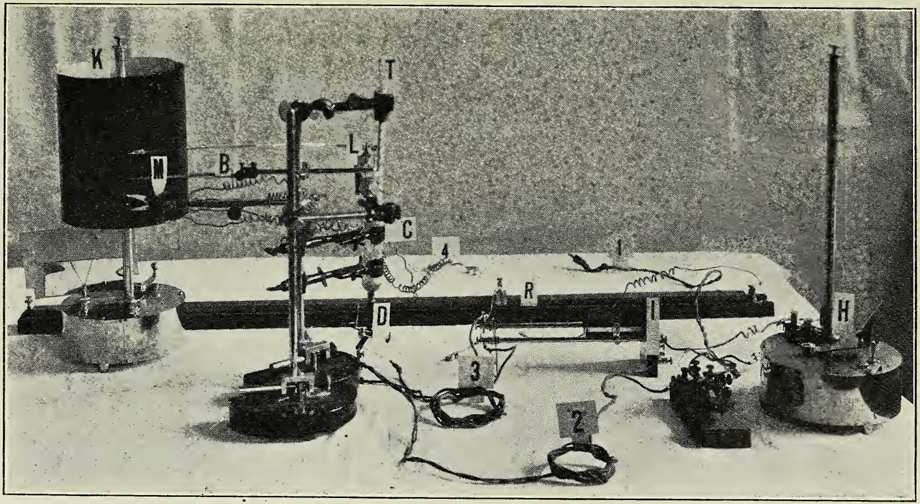

K
M
B
T
L
C
4
1
R
D
I
H
3
2

PLATE V.

Explanation of Figures

1, 2. Typical curves of the anterior region of the frog stomach showing influence of the duration of stimulus. Tetanizing current of two and a half and five seconds respectively was used. Note the relative heights, the similarity of plateau, and a slight difference in relaxation in the two curves. Note that the latency phase is very marked and rather long.

3. Typical curve of response of the middle region of the frog stomach caused by tetanizing current of about two seconds duration. Note a rapid decline in relaxation which is fairly typical of this region.

4A, 4B. Two responses of the posterior portion of frog stomach showing relative differences in position of a secondary contraction induced by some unknown cause on the relaxation of the first. A tetanizing current of two seconds duration was used entering as indicated by the signal in each case. Note the rather long latency in both.

5. Record of rhythmical contraction of frog stomach, a condition occasionally met with upon first mounting tissue of this region. This rhythm diminishes gradually in height and passes off usually within fifteen to twenty minutes.

6. Two curves produced on the same tissue from the frog esophagus, keeping the duration of the tetanizing stimulus constant in each case. Note the almost exact duplication of the first. A ten minute interval between compensated for fatigue factor. These two curves, due to equal stimulation, are instructive when compared to 1 and 2 where the duration of the stimulus varied.

7. Response of the duodenal region of the frog intestine when 0.5 vol. per cent ethyl alcohol is added. The first curve was produced by tetanizing current of five seconds duration, the much higher curve resulted after entering the alcohol and stimulating for same length of time.

8. Typical curve showing the occurrence of rhythmical contractions on the relaxation phase of frog stomach, after stimulation soon after mounting. This sort of curve often resulted if the tissue was stimulated before the rhythmical contraction ceased.

9. The gradation in responses in frog esophagus due to different amounts of resistance being thrown in by means of a rheocord. Beginning with the third curve shown note the diminution of height as successively 50 cm., 1 meter, and 20 meters of resistance wire were thrown in.

10, 12. Typical curves showing the effect of resistance in diminishing responses in earthworm muscle. The introduction of 20 meters resistance cuts the resulting response to about half of the preceding normal as can be seen here. Finally, weak strength of ethyl alcohol was added and a response recorded under its influence, with striking results in each case.

11. Typical curve of response of anterior end of frog esophagus, showing a slightly different contour from those of stomach mentioned above.

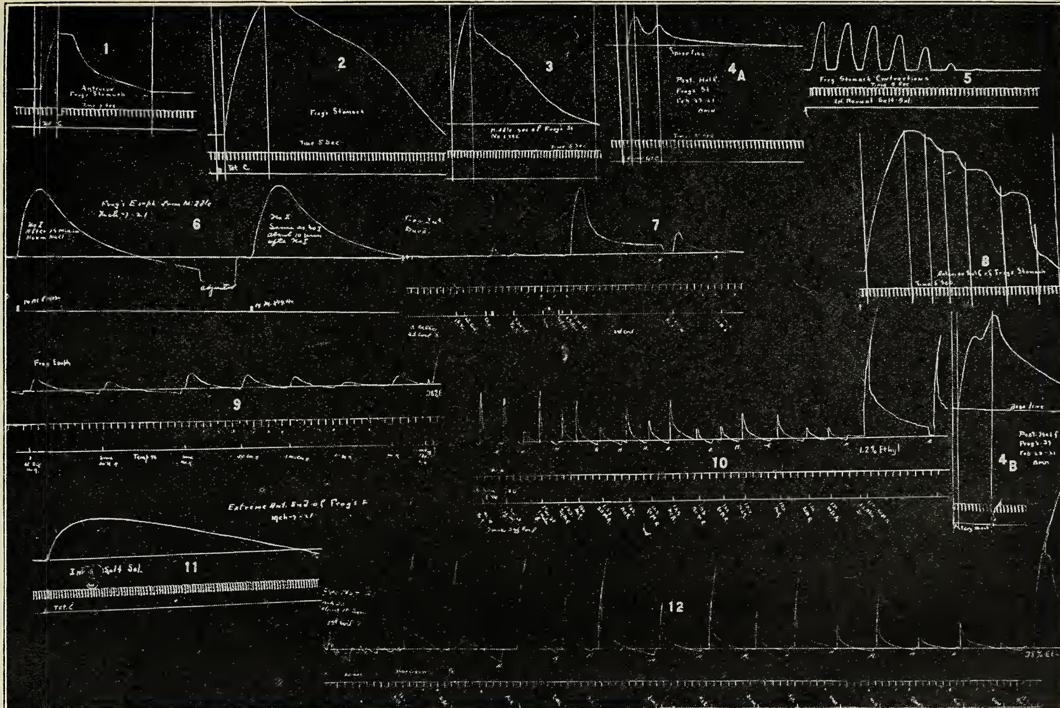

1
Anterior
Frog's Stomach
2
Frog's Stomach
Time 5 Sec.
3
Middle 3rd of Frog's St.
4A
Post. Half
Frog's St.
5
Frog Stomach Contractions
2% Normal Salt Sol.
6
Frog's Esoph.
7
8
9
Frog Esoph.
10
1.2% Ethyl
4B
Post. Half
Frog's St.
Base line
Extreme Ant. End of Frog's
11
Salt Sol.
12

PLATE VI

13, 14, 15, 16 and 17. Series of responses of frog esophagus when treated with 12.25, 9.00, 6.25, 3.12, 1.56 vols. per cent ethyl alcohol respectively. On comparison of relative heights from that of the normal in each case an index as to relative toxicity or sensitization in the series can be had. The forms of the resulting curves also show in the relaxation phase a graded change from a maintained plateau in the first to a nearly normal decline in the last.

18, 19, 20, 21, 22 and 27. Typical series of responses of earthworm muscles in regions of worm 57, showing gradations in height and form when subjected to various concentrations of ethyl alcohol. These records show unmistakably that the higher concentrations are markedly toxic, and that the weaker ones are decidedly sensitizing.

23. Fatigue responses in earthworm muscle under constant interval of stimulation, finally rejuvenated by treating with 0.25 vol. per cent ethyl alcohol.

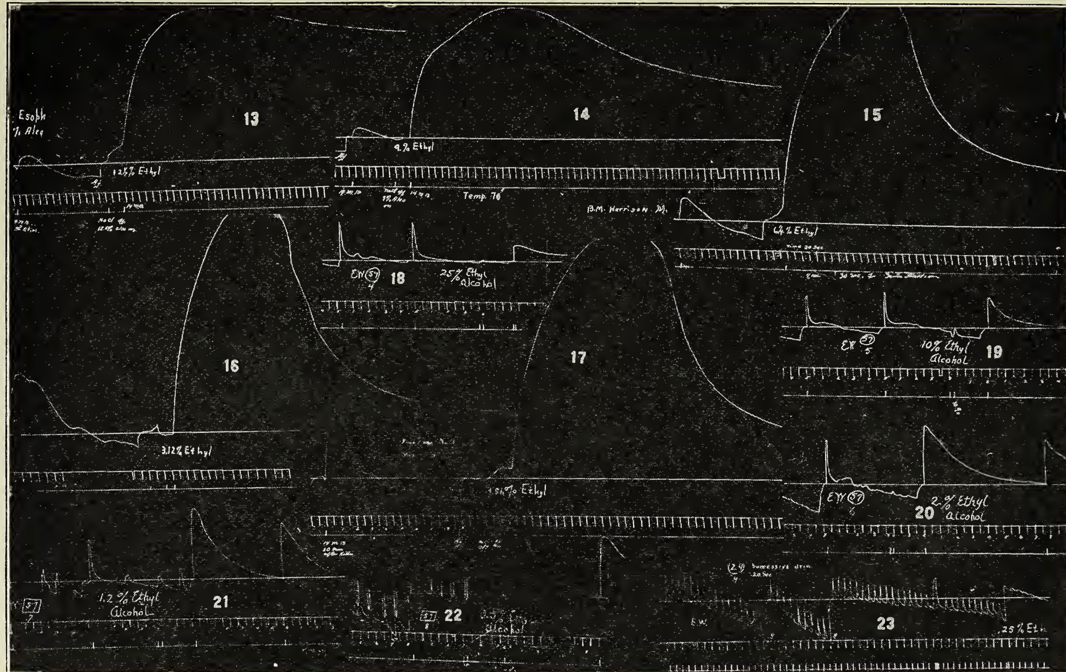
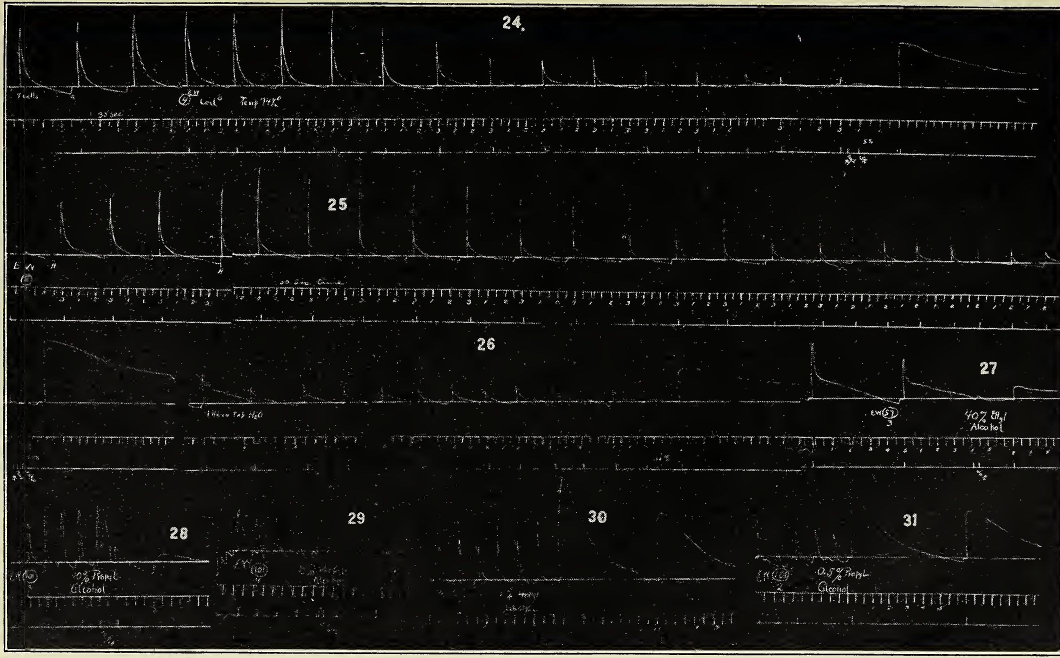

13
14
15
16
17
18
19
20
21
22
23
Esoph
12½% Ethyl
4% Ethyl
Temp 76
B.M. Harrison
6¼% Ethyl
25% Ethyl
Alcohol
3.12% Ethyl
1.56% Ethyl
10% Ethyl
Alcohol
2% Ethyl
Alcohol
1.2% Ethyl
Alcohol
25% Eth

PLATE VII

24, 25, 26. Three fatigue curves of earthworm muscle finally being treated at the end of the fatigue process to weak solutions of ethyl alcohol. In the first two note the gradual increase in height of response up to about the eighth stroke, which is a condition found to be constant and which we interpret as a sort of "treppe".

28, 29, 30 and 31. Typical modified curves produced by subjecting earthworm muscle to the various concentrations of propyl alcohol there stated. Marked similarity is evident in comparing these curves with those produced by the ethyl alcohol (see 18, 19, 20, 21 and 27).


24.
25
26
27
28
29
30
31
40% Ethyl Alcohol
0.5% Propyl Alcohol

NOTES ON THE DIFFERENTIAL VIABILITY IN GAMBUSIA[1]

S. W. GEISER

Barney and Anson (1921) in writing of the fluctuating sex-ratio in the common top-minnow, *Gambusia affinis* B. & G., have expressed (p. 61) conclusions with respect to a differential death-rate for the sexes quite at variance with data of my own. Briefly stated, they conclude that in the shipping of Gambusia for stocking ponds in mosquito-control work, the female has a higher death-rate than the males and they explain this upon the assumption that the male is more resistant to high temperatures than the female.

During the past year, I obtained from the Director of the U. S. Bureau of Fisheries Laboratory at Beaufort, North Carolina, two lots of these fish, totalling 1489 individuals. They were sent to Baltimore in fairly equal installments, and at different seasons of the year. On each occasion they were a little more than forty-eight hours in transit. One shipment (693 fish) was sent in cold

TABLE I

	November 12, 1920				March 22, 1921		
	Males	Females	Uncert.	Total	Males	Females	Total
Number of fish shipped	176	452	65	693	91	705	796
Percentage of population	25.3	65.2	9.4	99.9	11.4	88.5	99.9
Sex-ratio	100.0	256.8	...	...	100.0	774.7	...
Died in transit...	80	136	36	252	79	249	328
Percentage of dead population..	31.7	68.3*	...	100	24.08	75.9	99.98
Death-rate per thousand	454.5	300.8	553.8	363.6	868.1	353.2	412.0
Mortality index-number for males $\frac{\text{male death-rate}}{\text{female death-rate}}$	1.556				2.458		

[1] Grateful acknowledgements are due to Professor S. O. Mast for help and encouragement in studies on a part of which the present paper is based.

* Includes the "uncertains," i. e., young so small that their sex is not readily ascertained. Note: The death-rate of males in March, as compared with their death-rate in November is as 1.910 to 1. The death-rate for females compared in the same way is 1.174 to 1. In March, too, most of the females are heavily gravid.

weather (November); the other (796 fish) in warm weather (March). In the appended table I have presented data concerning these shipments, from which the following may be seen:

(1). The Gambusia in both shipments show a high general death-rate.

(2). At both seasons, the death-rate for males was greater than that for females.

(3). In the cold-weather shipment, the male death-rate was approximately 1½ times the female death-rate; in the warm-weather shipment, approximately 2½ times the female death-rate.

(4). The death-rate for females in the March shipment was only 1 1/6 times that of the November shipment.

(5). The death-rate for males in the March shipment was practically double that of the November shipment.

From the foregoing it is evident that the male is more susceptible to injuries incidental to shipment than the female, and that temperature is not the main factor involved in the high general death-rate.

This latter conclusion is further supported by the results of a series of experiments in which Gambusia were, by ten-minute stages, brought into water of increasing temperature. The fish apparently suffered no discomfort when the water in their container was thus, in forty minutes, raised through 20°C and neither sex showed any marked or peculiar behavior. Therefore, as a result of these experiments, I am convinced that the cause of the high general mortality-rate in shipments of Gambusia is due, rather, to injury in catching, and to crowding in the container, than to warming, more or less rapid, of the water. In the causation of the higher death-rate of the males, injury of the intromittent organ *may* also have a part.

The conclusion of Barney and Anson, regarding the supposed higher death-rate of females, rests, in my opinion, on very slender support. They say in part:

It might be thought that the higher temperatures produced a high mortality rate in males. This is not the case, however, for in September of each year there is a decided increase in male ratio, even though the average mean-temperature of the air and water of this vicinity is about as high in September as it is in May or June when the male ratio is decreasing. *Neither is such mortality probable in view of actual experience. One of the writers in stocking a pond in Alabama in August, 1918, carried several cans of Gambusia on a railroad journey of about twenty-four hours, and on liberating them in the pond, found that a large number* *of females had died, but no males.* This mortality had doubtless been caused by the rapidly increasing temperature of the water in which the fish were shipped. It is evident, *then, that the male Gambusia is somewhat more resistant to higher temperatures than the female.* That the significance of temperature in this matter is nil is suggested by the fact that the writers have seen on several occasions Gambusia thriving with no mortality in pools where the water registered from 97 to 103 degrees Fahrenheit. (Italics mine.)

It seems to me that the fact that no males were found by Barney and Anson in the death population, while many females were, has little or no significance, for there is nothing in the passage cited, or elsewhere in the paper, to show that the sex-ratio of the population as shipped had been ascertained. It will be seen from the table that in my shipments from 68.3 per cent to 75.9 per cent of the fish that were dead on arrival were females. In view of the fact that the sex-ratios were 256.8 and 774.7 females, respectively, to every 100 males it will be seen that this is owing to the fact that the males were so greatly outnumbered by the females. Is it not possible, then, that the low death-rate in the males claimed by Barney and Anson may have been due to a deficiency in the number of males present? If this was true, it might be accounted for by the operation of either or both of two causes: (a) at this season of the year, the percentage of males in a population, is about at its low-point,[2] or, (b) the males, being much more agile, and of markedly smaller size than the females, often either avoid or pass through the net, during the collecting. Barney and Anson do not say what kind of net was used in making the collection, but in the course of their paper (p. 55) they state that all collections summarized in their tables were made with quarter-inch meshed seines and dipnets. Judging from the results of my own experiments, I am sure that with such a net, many Gambusia pass through the meshes, and that most of these are males. It may be, then, that in the collection made by Barney and Anson, a large proportion of the males escaped, and if this is true, it is a simple matter to account for the lack of males in the dead population referred to.

On the basis, merely, of the sex-ratios and mortality rates of these two collections sent to me from Beaufort, I should be quite unwilling to draw general conclusions as to the differential viability of the sexes in Gambusia. Mr. S. F. Hildebrand, however,

2 I am assuming that Barney and Anson are correct in their conclusions on this point; I have no data of my own.

who in connection with his work in the U. S. Bureau of Fisheries and the U. S. Department of Public Health has shipped literally hundreds of thousands of these fish, tells me that his experience also points to a greater male death-rate in transit. It may, then, be safely concluded that in general the female Gambusia survive shipment better than the males.

LITERATURE CITED

Barney, R. L. and Anson, B. J. (1921) Seasonal abundance of the mosquito destroying top-minnow, *Gambusia affinis,* specially in relation to male frequency. *Ecology,* Vol. II, No. 1, pp. 53-69 (Jan.).

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DISTRIBUTION OF THE EUROPEAN ELM SCALE

ALBERT HARTZELL

On May[1] 27, 1919, an American elm on the Iowa State College grounds at Ames was found to be infested with European elm scale (*Gossyparia spuria*). Since the above date several other Iowa records have been added to our list and a considerable amount of information has been obtained regarding the distribution of this species in the United States and Canada through correspondence with State Entomologists, the U. S. Bureau of Entomology and Agricultural Experiment Station workers in states in which scale was thought likely to occur.

The European elm scale was introduced into the United States from Europe in the latter half of the nineteenth century. The exact date will probably never be known. It was first brought to the attention of the United States Department of Agriculture[2] by Mr. Charles Fremd of Rye, New York, in June, 1884, who complained that the elms in his nursery were badly infested with a bark louse. The insect in question was finally determined in 1889 from material sent in by Mr. J. G. Jack of Cambridge, Massachusetts. The spread of the species was rapid as was pointed out in 1897 by Lintner[3] in his 12th report, representing six states and the District of Columbia, including such widely scattered records as Palo Alto, California, Carson City, Nevada, East Lansing, Michigan and Burlington, Vermont; and it was known to occur along the Hudson from New York City to Troy. Since that time the spread of the insect along the main lines of travel has progressed until now it is found in twenty-seven states, the District of Columbia and the Provinces of Ontario and Quebec.

That infested nursery stock is a contributing factor of great importance in the dissemination of this pest is shown by a study of the accompanying map. Long Island, the Hudson and Mohawk Valleys in the east and the Union Pacific Railway and its branches in the west constitute the main thoroughfare of dissemination.

Gossyparia spuria is a native of Europe where it has been known to science for over a century, and has been reported from England,

1 Jour. Ec. Ent., Vol. 12, No. 4, p. 351 (1919).
2 Howard, L. O., Ins. Life, Vol. 2, p. 35 (1889).
3 Lintner, J. A., 12 Rep. Ins. N. Y., p. 294 (1897).

France, Germany, Bohemia and Italy. It appears to be quite generally distributed throughout the Continent. Its distribution in the United States is closely correlated with the distribution of *Ulmus fulva* and *U. americana,* its more common hosts. Roughly speaking, the red elm (*Ulmus fulva*) occurs from the 100th meridian eastward and southward to Texas and Florida. The American elm has approximately the same distribution except that in western Canada it extends northward to within half a degree of the southern boundary of Alaska. West of the 100th meridian the elms do not normally occur and the spread of the scale beyond the Rocky Mountains has been due no doubt to infested nursery stock.

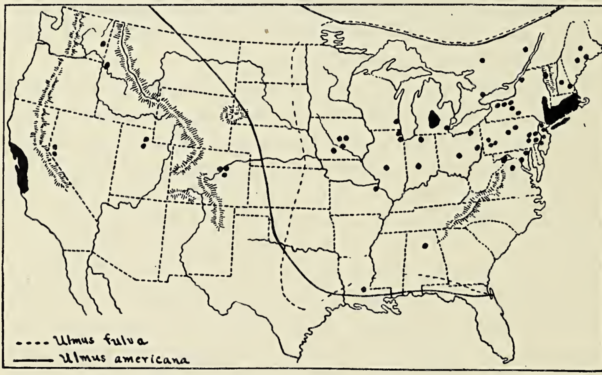

Fig. 31. Map showing the distribution of the European Elm Scale (*Gossyparia spuria*). Curved dotted line represents the limits of *Ulmus fulva.* Curved solid line represents the limits of *Ulmus americana.* Area in which the scale has been reported from many localities represented in solid black. The information regarding the distribution of *U. fulva* and *U. americanus* furnished through the courtesy of Dr. E. N. Transeau.

The distribution of the European elm scale is represented by the accompanying map (Fig. 31) on which are noted over 100 locality records. There are three regions of general distribution: (a) the New England States and Middle Atlantic States, including the Provinces of Ontario and Quebec; (b) the Central States; and (c) California. The New England States and Middle Atlantic States form a region in which the scale is present in greatest abundance. Practically all the records in this region come from the territory between the Potomac and St. Lawrence rivers and include more than half the locality records in this list. In the Central States the records are fewer and more scattered. California represents the third region of general distribution with a large number of records in the vicinity of Sacramento and Palo Alto. The isolated records of Spokane, Washington, Logan and Salt Lake, Utah, Reno, Nevada, and Denver, Colorado, are examples of infestation along the main routes of commerce which may serve as centers of infestation for the surrounding country. With the exception of Louisiana and Alabama, we have no records from the states south of Ohio river. Negative replies were received from the entomologists of Kentucky, Tennessee, Arkansas, Mississippi, North Carolina, South Carolina, Georgia, and Florida, which would indicate at least that the scale is not present in any numbers. The insect does not seem to have extended its range into the arid region of the southwest, not is it known to occur in Minnesota, Montana or Oregon. A glance at the map shows that the geographical distribution of the scale does not coincide exactly with the distribution of its hosts. This is especially true in the southern part of its range. While elms occur as far south as Texas and Florida, the insect has very seldom been reported south of Ohio river. On the other hand in California and Nevada, in a region where its hosts do not occur normally, it seems to have found climatic conditions favorable, and is a serious shade tree pest to the introduced elms. Why this insect prefers the American elms to the European species on which it doubtless originated has never been satisfactorily explained.

LOCALITY RECORDS OF GOSSYPARIA SPURIA FOR THE UNITED STATES AND CANADA

Locality Record	Authority
Alabama	
(No locality given	E. H. Hinds
California	
Calusa	H. S. Smith
Modesto	H. S. Smith
Palo Alto	H. S. Smith
Palo Alto	
Palo Alto	LeRoy Childs
Sacramento	LeRoy Childs
San Rafael	H. S. Smith
San Jose	H. S. Smith
San Jose	E. R. Sasscer
San Jose	F. B. Herbert
Santa Clara	H. S. Smith
Santa Clara Co.	E. R. Sasscer
Stanford	H. S. Smith
Stanford	E. R. Sasscer
Stockton	H. S. Smith
Ukiah	H. S. Smith
Colorado	
Denver	C. P. Gillette
Fruita	G. M. List
Golden	G. M. List
District of Columbia	
Washington	J. A. Lintner
Washington	E. R. Sasscer
Connecticut	
Cheshire	W. E. Britton
Colchester	W. E. Britton
Hartford	W. E. Britton
Meriden	W. E. Britton
New Haven	W. E. Britton
Sharon	W. E. Britton
Sound Beach	W. E. Britton
Southington	W. E. Britton
South Norwalk	W. E. Britton
Yatesville	W. E. Britton

Locality Record	Authority
Idaho	
Lewiston (?)	A. L. Melander
Illinois	
Chicago	C. B. Dull
Chicago	P. A. Glenn
Springfield	J. G. Sanders
Springfield	W. P. Flint
Indiana	
(Northern part)	W. A. Price
Indianapolis	H. F. Dietz
Indianapolis	H. Morrison
*Iowa	
Ames	Albert Hartzell
Des Moines	Albert Hartzell
Ontario	F. A. Fenton
Waukee	F. A. Fenton
Louisiana	
Ambler	E. R. Sasscer
Maine	
Augusta	E. R. Sasscer
Castine	J. O. Johannsen
Orono	J. O. Johannsen
Maryland	
Baltimore	E. R. Sasscer
Massachusetts	
Amherst	C. P. Lonsbury
Boston	C. P. Lonsbury
Brighton	W. O. Hollister
Brookline	C. P. Lonsbury
Cambridge	C. P. Lonsbury
Jamaica Plains	J. G. Jack
Malden	E. R. Sasscer
Springfield	E. R. Sasscer
Michigan	
Agr. College	T. D. A. Cockerell
Agr. College	R. H. Pettit
Detroit	E. R. Sasscer
Detroit	W. O. Hollister
Detroit	R. H. Pettit
East Lansing	R. H. Pettit
Grand Ledge	R. H. Pettit
Lansing	R. H. Pettit
Pine Lake	R. H. Pettit
Williamston	R. H. Pettit
Missouri	
St. Louis	E. R. Sasscer
Nevada	
Carson City	S. B. Doten
Reno	S. B. Doten
Reno	R. R. Graves
New Hampshire	
Boscaven	C. R. Cleveland
Portsmouth	C. R. Cleveland
New Jersey	
Englewood	E. R. Sasscer
Montclair	E. R. Sasscer
Princeton	E. R. Sasscer
South Orange	E. R. Sasscer

Locality Record	Authority
New York	
Albany	J. A. Lintner
Albany	W. O. Hollister
Athens	E. P. Felt
Binghampton	E. R. Sasscer
Brooklyn	E. R. Sasscer
Brooklyn	E. P. Felt
Castleton	E. P. Felt
Catskill	J. A. Lintner
Delmar	E. P. Felt
Flushing	E. P. Felt
Ghent	J. A. Lintner
Ithaca	E. R. Sasscer
Locust Valley	E. R. Sasscer
Marboro	J. A. Lintner
Mechanicsville	E. P. Felt
Mount Vernon	E. P. Felt
New Drop	E. P. Felt
New York City	E. R. Sasscer
Nyack	E. P. Felt
Ogdensburg	E. P. Felt
Oyster Bay	E. P. Felt
Poughkeepsie	E. R. Sasscer
Poughkeepsie	W. O. Hollister
Rhineheck	E. P. Felt
Rochester	E. P. Felt
Round Lake	E. P. Felt
Rye	J. A. Lintner
Schenectady	E. P. Felt
Syracuse	E. R. Sasser
Tarrytown	E. P. Felt
Tarrytown	E. R. Sasscer
Troy	J. A. Lintner
Westbury	E. R. Sasscer
Woodmere	E. R. Sasscer
Ohio	
Cleveland	J. S. Houser
Columbus	A. F. Burgess
Columbus	J. S. Houser
Marietta	J. S. Houser
Ontario	
(Southern part)	J. W. Swaine
Ottawa	J. W. Swaine
Toronto	C. J. S. Bethune
Pennsylvania	
Center College	E. R. Sasscer
Norwood	E. R. Sasscer
Oakmont	E. R. Sasscer
Pencoyd	E. R. Sasscer
Philadelphia	E. R. Sasscer
Pittsburgh	E. R. Sasscer
Winnewood	E. R. Sasscer
Wilkensburg	E. R. Sasscer
Wilkesbarre	E. R. Sasscer
Quebec	
(Western part)	J. W. Swaine
Rhode Island	
Kingston	E. R. Sasscer
Providence	E. P. Felt

Locality Record	Authority
Utah	
Ogden	E. R. Sasscer
Salt Lake City	E. R. Sasscer
Vermont	
Burlington	Prof. Perkins
Virginia	
Enola	E. R. Sasscer
Washington	
Spokane	E. R. Sasscer
Spokane	A. L. Melander
West Virginia	
Harpers Ferry	E. R. Sasscer
Wisconsin	
Milwaukee	J. G. Sanders

Since the above list was compiled the following additional Iowa records have been noted: Indianola, B. M. Harrison; Des Moines, H. Ness; Story City, F. A. Fenton; Nevada, Albert Hartzell.

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THE READJUSTMENT OF THE PERIPHERAL LUNG MOTOR MECHANISM AFTER BILATERAL VAGOTOMY

T. L. PATTERSON

It has been shown by Carlson and Luckhardt (1) in crucial experiments (1 to 2 hours) that destruction of the medulla or section of the vagi in the frog leads immediately to a permanent hypertonus or incomplete tetanus of the lung neuro-muscular mechanism, which makes the lung practically non-functional and useless as a respiratory organ. The present work however, was undertaken with the idea of ascertaining whether this hypertonic condition observed by these authors is permanent or temporary.

The older literature dealing with the respiratory movements of the frog, which it is not necessary to go into here, is more or less conflicting and inadequate in itself to explain the true lung reaction resulting from destruction of the medulla or section of the vagi and needs re-investigation, especially in view of the recent results of Carlson and Luckhardt in acute experiments.

The anatomy of the frog's lung is well known, it being a paired muscular sac having numerous muscular septa on the interior surface dividing it into small spaces or alveoli. The septa extend only a few millimeters from the lung wall, so that the larger part of the lung cavity is a large single air space. There are no bronchi and no true trachea, the tracheal sac having essentially the same structure as the rest of the lung and probably carrying the same respiratory function. The entire wall of the lungs is covered with smooth musculature which extends into the smallest septa on the inner surface, while more or less definite external muscular strands follow the course of the main pulmonary blood vessels on the lung surface. The lung musculature is so arranged that contraction, even of the septal musculature, will reduce the size of the lung cavity, or raise the intrapulmonary pressure in of the septal musculature would be analogous to that of the bron- case the air in the lung is not free to escape. Hence, the action chial constrictor muscle of the mammalian lung.

According to the histological studies of Arnold (2), Smirnow (3), Cuccate (4) and Wolff (5) there are numerous ganglia, as well as isolated ganglion cells (multipolar and bipolar) along the course of the main vago-sympathetic nerve trunks on the surface of the lung, the nerve fibers of which are both medullated and non-medullated. In addition, there is a plexus of fine non-medullated nerve fibers which surrounds the strands of the lung musculature. These nerve plexuses and ganglion cells are most abundant at the base of the lung and Arnold points out that these are histologically identical with those of the frog's heart. They are also probably identical, both as to histology and function, with the ganglionic plexuses (Auerbach) in the wall of the gut, especially as the lung is a diverticulum from the foregut (esophagus), therefore, it would be reasonable to look for a gradual physiological readjustment of the peripheral lung motor mechanism similar to that which gradually occurs in the case of the gastro-neuromuscular mechanism of the bullfrog (6) after section of the vagi or the splanchnic nerves.

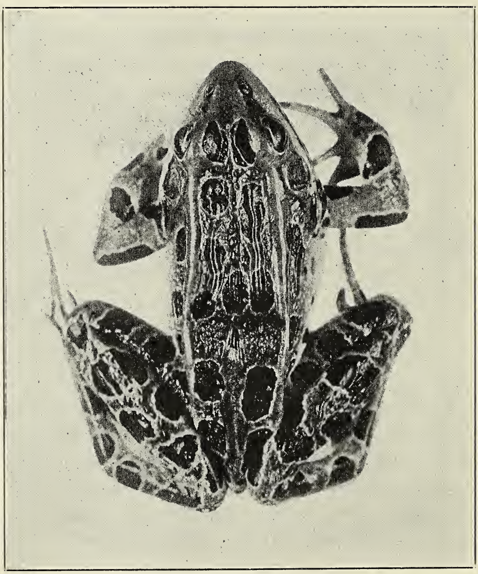

Fig. 31a. Frog 10, *control,* showing the normal contour of the flanks. (After 6 weeks as a control animal bilateral vagotomy was performed. It then lived 247 days and was the only animal in which complete physiological readjustment of the peripheral lung motor mechanism occurred.)

In the frog, the external respiratory acts consisting of buccal movements, closing of nares, expiration and inspiration or swallowing air, occur in a coördinated and orderly sequence, the buccal or passive movements proceeding rhythmically between the swallowing acts, so that there are several buccal movements between each swallowing act. This is the usual type of buccal movements exhibited in the frog although in exceptional cases there may be at times in certain animals a perfect synchrony between these movements and the actual swallowing of air (inspiration). It should be emphasized here, that the external respiratory mechanism of the amphibians differs from that of all other air-breathing animals in that the air enters the lungs under positive pressure due to the act of swallowing, therefore, this might indicate possibly that the respiratory center in the medulla of this animal is anatomically and physiologically identical with the center for deglutition.

The buccal or passive movements are distinct from the quick respiratory movements of the flanks, the latter being due to the act of inspiration or the swallowing of air which is preceded by the opening of the glottis and the escape of some air into the buccal cavity. This results first in a diminution in the size of the lungs with a corresponding falling in of the flanks which is then quickly compensated for by a distension of the lungs which in most animals show a periodicity similar to the Cheyne-Stokes type of breathing in mammals.

The experiments forming the basis of this report were made exclusively on the common laboratory frog (*Rana pipiens*). Healthy, vigorous animals were selected in pairs, one of which was kept as a control, while in the other, one or both vagi were sectioned in the region of the neck after anaesthesia. The delicate technique for this operation in this species of frog consists in making two oblique incisions through the skin on either side of the median line, ventral, about ½ cm. distant and close to the anterior tips of the shoulders as represented by a line drawn from this point laterally about 1 cm. in length to a point slightly posterior and just internal to the articulation of the superior and inferior maxillary bones on either side. These two incisions expose the cervical fascia on either side at its attachment along the anterior scapulo-clavicular borders. Few blood vessels are present and if the fascia is carefully separated no hemorrhage results. The fascial separation beyond this region now becomes very easy until the thin sheet of prevertebral fascia is reached which is

Fig. 31b. Frog 10, 9 days after bilateral vagotomy, showing complete absence of the normal contour of the flanks. Note the straight body lines as compared to the control in figure 31a.

about on a line of the transverse processes passing obliquely downward and inward from the base of the skull and extending into the thorax. This latter sheet of fascial membrane is now pierced, which exposes the levator anguli scapulae muscle, over the anterior border of which courses the vagus nerve and the internal jugular (Vena jugularis) and musculo-cutaneous (Vena musculo-cutanea) veins. The incision is held open by the spring of a small pair of ordinary forceps (preferably curved points) and then by means of a small pair of mouse-toothed or eye forceps (iris forceps) the nerve is carefully separated from the adjoining veins to which it is bound by connected tissue. This is best accomplished by freeing the nerve either between the two veins mentioned or just lateral to the internal jugular vein at the anterior border of the levator anguli scapulae where it crosses and sectioning the nerve just below the origin of the recurrent laryngeal branch. Section of the nerves at this point destroys not only the pulmonary branches to the lungs but also the cardiac and gastric branches destined for the heart and stomach. In unilateral section only the right or left vagus nerve was cut. In the case of bilateral vagotomy, both vagi were always sectioned at one operation and the skin incisions closed with four sutures. After recovery of the animals, direct observations were made on the visible changes in the contour of the flanks and the external respiratory movements and compared with that of the normal or control animal.

The animals were kept under observation for periods of several weeks and even months in many cases. During this time they were kept in a large vivarium which was divided into small compartments in which the animals were kept in pairs (control and vagotomized). This was provided with running water and the animals in all the later experiments were fed on caterpillars and earthworms in order to keep them in first class condition, for any depression in the animals might defeat the object of the experiment. To further control any possibility of depression resulting from the confinement of the animals, the vagi were sectioned in many of the control animals, five to eight weeks after the cutting of the nerves in the first animal but these latter or control animals always reacted in exactly the same manner as the former. Finally, all the animals at the close of the respective experiments were autopsied and the condition of the lungs and other visceral organs observed.

Since the results of this study have been published in full in the American Journal of Physiology (November, 1921), Vol. LVIII, No. 1, it is necessary here only to give a resumé of some of the more important conclusions.

Bilateral vagotomy in the frog (*Rana pipiens*) destroys the inhibitory control over the peripheral lung automatism leaving it free to exert its full influence on the lungs without any check, hence the lungs contract and pass into a state of hypertonus or lung tetanus to such a degree as to nullify their function. The normal contour of the flanks in these animals disappears and the body line becomes straight or even curved in.

In unilateral section of the vago-sympathetic nerve there is loss of the inhibitory control over the peripheral lung automatism on the side of the section only, the opposite lung being unaffected, thus showing that the nerve action is unilateral.

In both unilateral and bilateral section of the vago-sympathetic nerves there is a gradual physiological readjustment of the peripheral lung motor mechanism which usually starts from 12 to

Fig. 31c. Frog 30, 7 days after unilateral section of the left vago-sympathetic nerve, showing total absence of the normal contour of the flank on the side of the nerve section only. Compare with the normal contour of the flank of the right side.

21 days after the nerve section when the lung begins to be distended by swallowed air, pushing out the flanks and finally forming "olive-shaped" prominences. This readjustment was partial in all the animals with the exception of one, which lived for an extended period of a little over 8 months, the complete physiological readjustment occurring at the end of about 7½ months. In other animals living for periods of from 2 to 5 months, those of 5 months standing always showed a greater degree of physiological readjustment than those of less duration.

In recent bilateral vagotomized animals up to periods of from 2 to 3 weeks air is found more constantly and usually in greater amounts in the stomach and intestine than in similarly operated animals of longer standing. This indicates that the air is forced into the stomach by the act of swallowing because of the persistently constricted lungs aided probably by a hypotonic stomach, at least in the early stages.

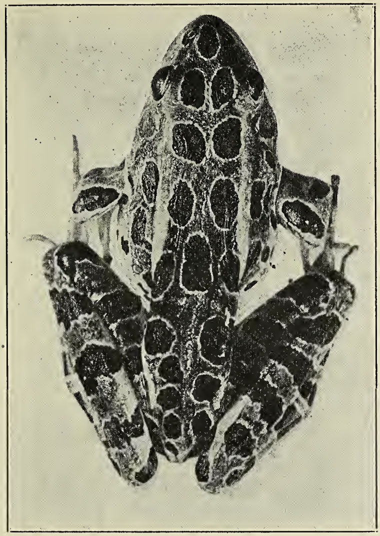

Fig. 31d. Same animal as in figure 31b, 32 days after bilateral vagotomy, showing a partial physiological readjustment of the peripheral lung motor mechanism. Note the "olive-shaped" prominences.

All the autopsy findings confirmed the above results.

Bilateral vagotomy has little or no effect on the buccal movements, whereas the actual respiratory movements (opening of glottis and swallowing of air into lungs) are temporarily abolished, but these movements gradually return with the physiological readjustment of the peripheral lung motor mechanism.

The lung readjustment in these long time experiments is not due to a gradual weakening of the animals from age and starvation since animals when fed and kept in close confinement react in a similar manner after unilateral or bilateral vagotomy as do normal animals which have not been so kept. Furthermore, the failure of the vagotomized lungs to contract down to practically a solid mass on death or destruction of the medulla in these experiments is evidence that this readjustment is not due to a vagus regeneration. It may be implied, therefore, that this physiological readjustment of the vagotomized lung is brought about through some special activity of its peripheral neuro-muscular mechanism.

REFERENCES

(1) Carlson and Luckhardt: Am. Jour. Physiol., 1920, LIV, 55.
(2) Arnold: Virchow's Arch., 1863, XXVIII, 433.
(3) Smirnow: Anat. Anzeiger, 1888, III, 258.
(4) Cuccate: Int. Monatschr. f. Anat. u. Physiol., 1888, V, 194.
(5) Wolff: Arch. f. Anat., 1902, 179.
(6) Patterson: Am. Jour. Physiol., 1920, LIV, 153.

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STATE UNIVERSITY OF IOWA

METHODS OF TEACHING PARASITOLOGY

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(*Posthumous*)

The fact that animal parasites are important as disease producing agents has been known for a great many years. Thought, consideration, study, and emphasis on the question of parasitism have come in waves; at times it was looked upon as one of the most important factors to be dealt with, while at other times or periods it has received almost no attention and parasites have been looked upon as more or less unimportant as disease producing agents. But the necessity for the protection of our livestock from disease has grown, being governed largely by the supply and demand, together with the rearing of animals under more or less intensive conditions, the modern commercial method of handling animals for food purposes, the very general interchange of breeding stock, the numerous stock shows, and other conditions that make possible the spread of parasitic diseases. Further, it has been proven that many parasites are carriers, directly or indirectly, of the causes of specific diseases and thus parasites as well as all classes of disease-producing agents have of necessity received attention. While the full importance of animal parasites was not fully appreciated until more or less recent years, our knowledge regarding them has been gradually increased, as a result both of natural infestation and of experimental work, until today we have come to understand the very great importance of parasitism and animal parasites in relation to the cause and spread of disease among both man and animals.

Studies in parasitology, as strictly veterinary, have been introduced into practically all courses in veterinary medicine within the last fifteen to twenty years. This, together with the great amount of experimental work and investigation being done and the general discussion that is taking place on the question of animal parasites, speaks fully for the importance of this subject and the attention that it is receiving by the medical world.

The object of this report is to briefly outline a systematic plan for a method of teaching parasitology to veterinary students with the object of adequately covering the subject and at the same time not to encroach upon the time which seems essential to be devoted to other studies. This becomes a very difficult problem when we stop to consider *the number of animal parasites* found affecting the *different species* of *domestic animals* which must necessarily be covered or dealt with in a course in veterinary medicine. In that the subject can receive only its apportioned amount of time as related to other subjects in a veterinary curriculum, the general tendency to limit the number of credit hours a student can carry, and the need for the introduction of new subjects and more time for certain subjects already offered, makes it necessary for one teaching parasitology to be very careful in the arrangement of the subject matter to be given, to find time to cover even the more important phases. This includes the laboratory work, the subject matter of the lectures, the selection of the parasites and organs to be used for study and demonstration in the laboratory work and the listing of references. In those cases where condensed and up-to-date material is not available for reading, the instructor should compile such materials for the students, with the object that a maximum amount of ground may be covered in a minimum time. Time may further be conserved by the use of drawings and charts in connection with fresh and preserved specimens studied in the laboratory, by the study and comparisons in all classes in pathology of tissue changes resulting from animal parasites with lesions due to other causes, and lastly by having the students make personal use of all the parasites and parasitic conditions met with in the animals that come under their observation in the clinic and post-mortem work. Such procedure is strictly clinic work, is supplementary to parasitology, and is the ideal way for a student to become familiar with all phases of a particular form of parasitism.

PREPARATION OF THE STUDENT

In taking up the subject of parasitology with veterinary students, it is essential that they have had some general and fundamental work in zoology. The teacher must assume this. The work in general zoology given to veterinary students should be of such a nature as to familiarize them with methods of study, classification, life history, biological laws, morphology, and the general principles of zoology, including both vertebrates and invertebrates in a way that would serve as a foundation to the principle of structure and function in anatomy and physiology, and to the study of the various forms of life found parasitic on our domestic animals.

If this suggestion were to be carried out, it would mean that the work in zoology offered to veterinary students in most of the departments of zoology in the various institutions in the country would have to be especially outlined for veterinary students, as any one of the various studies for beginners in zoology offered to students in other courses is too limited in its scope and is arranged as one of a series of studies — one being prerequisite to the other. To overcome this difficulty departments of zoology should offer work to veterinary students complete in itself and outlined to meet as nearly as possible the special needs of the student pursuing work in veterinary medicine.

CLASSIFICATION OF ANIMAL PARASITES

Inasmuch as there seems to be no better way for veterinarians it is undoubtedly absolutely essential that we should classify and study animal parasites as they are classified in systematic zoology. The veterinarian should be able to place in its proper zoological position any known parasite. After the student has become familiar with the zoological grouping of the various forms he will be able when engaged in the practice of veterinary medicine to deal without confusion with parasites according to the species of animal attacked or according to the part invaded, for example, — intestinal and lung parasites; but unless the individual concerned is able to place the parasite under consideration in its proper zoological position, he will not make much progress in a scientific way. The proper classification of a parasite is, of course, more or less essential to diagnosis, treatment and prevention. The various forms of animal life to be dealt with in parasitology offer a very definite and characteristic morphology as well as conform to definite biological laws, therefore, we would emphasize that the various forms of animal life found parasitic on our domestic animals should be looked upon as groups of disease-producing agents to be classified and studied as thoroughly and systematically as are microörganisms. When the student has completed the study he should look upon and have an understanding of animal parasites as comparable with that which would be expected of a student completing studies in pathogenic microbiology, or of a student of systematic and economic entomology.

THE GROUND TO BE COVERED

The subject matter of the study of parasitology should be covered by means of lectures, laboratory work, demonstrations, and reference reading. The subject matter to be covered by lectures must, of necessity, be condensed, systematically arranged, and while it should not include a species description of the parasite, it should include generic characters. The species description takes a great deal of time, and can be much better handled by being given in the form of a printed outline for use in the laboratory. For example — in taking up the Ascaridae, the lecture work would cover briefly the group, class, order, family and genus with a list of the different species. From this point the lecture work would include the question of ascariasis in all species of domestic animals as outlined later. The laboratory work should consist of an examination of the more important animal parasites with special emphasis on the morphology for purposes of identification, for an understanding of the injurious action of the parasite and those morphological structures which have to do with reproduction, life history and indirectly with methods for control. The laboratory work should further consist of demonstrations of gross specimens of the parasite and tissues showing lesion. In many cases histological preparations are indicated and all can be supplemented to good advantage by the use of charts, drawings, and lantern slides in the lecture room or laboratory. The reference reading assignment must be definite, and not require that a student read extensively to obtain a minimum amount of information.

THE SCOPE OF WORK

The subject of parasitology as taught to veterinary students should include only those forms of animal life that are visible to the naked eye except for the few cases cited below, or in other words it should not attempt to cover microörganisms even though many such are in the animal kingdom. Realizing from experience that there will of necessity be some overlapping, it is to be counted as a gain to the student rather than a loss or unnecessary duplication; for example, piroplasma, trypanosoma, coccidia, sarcosporidia and all microscopic forms, even though they seem to have a protozoan relationship, should be dealt with in bacteriology or microbiology and only indirectly referred to in parasitology. A discussion on animal parasites to be complete must, of course, include the lower forms of animal life, but our point is, while we would in a general way and in our classification include the above microscopic forms, we would leave specific information and detailed study of these forms to the study of microbiology. On the other hand, acarina (Ex. Demodex and Laminisioptes cysticole), which require magnification to determine, should be looked upon as belonging strictly to parasitology. Local conditions as they exist in the various institutions might logically call for some variation in this regard.

MORPHOLOGY

The work in parasitology should familiarize the student with the morphology of the adult parasite including external and internal structures, emphasizing such external markings as size, structure and any others that will be useful in the identification of the parasite. Morphology should further include the organs of reproduction, eggs, or ova, embryos, larval and pupa forms, as well as the adult. In fact any markings or structures, including all *stages* of *development* characteristic of different forms, that would in any way be of value in identifying the parasite or form of parasitism and that have a bearing on methods of control, should be included.

LIFE HISTORY

Since the control and eradication of animal parasites is largely a matter of prevention, it is essential that the student be familiar with every phase of the life history including the atmospheric and climatic conditions and geographical and geological formations favorable to its existence, continuation and spread. In taking up the life history of parasites we should start with the eggs, ova, and embryos as they are formed or as they leave the adult, and trace them through their various stages of development and migrations as far as these are known until they have reached the host of the mature parasite and are again producing new generattions. We must impress upon the student the fact that the great advantage in combating certain parasites and often the only possible way to success is to direct our efforts at the stage of development most susceptible to destruction, and that successfully and intelligently to carry this out we must be familiar with the *morphology* of *every* stage of *development* and the *complete life history* of the parasite. When we are considering the life history, the following points will necessarily come up for consideration:

(a) Is it necessary for the young to leave the host to complete its life cycle?
(b) By what channels and under what conditions are the young forms expelled from the body?
(c) What is the location in Nature?
(d) Is an intermediate host necessary?
(e) What is the length of time and the condition under which the

young may remain outside the body of the host and still survive?

(f) How do the different forms gain entrance to the body?
(g) What are the different stages of development, metamorphosis?
(h) At what stage or stages is the parasitic action exerted?
(i) By what method does it become located in a particular organ or structure, its migrations in the body?

ACTION OF THE PARASITE

What is the pathogenic effect of the parasite upon the host?

In what way is the particular species injurious outside its direct or strictly parasitic action?

Does the parasite carry infection directly or indirectly?

LESIONS

What structural changes and lesions result from the presence of the parasite, its method of feeding, its migrations, and forms of growth?

What lesions are typical of the parasite?

What is the pathology of the lesion after the parasite has left?

What must be considered in carrying out steps in the differential diagnosis of lesions?

SYMPTOMS, TREATMENT AND PREVENTION

These are points upon which there are differences of opinion as to just where the final word should be said. Some are of the opinion that these points should be covered in detail by the instructor giving the work in parasitology, while others are of the opinion that this phase of the subject should be dealt with in Theory and Practice (medicine). Granting that local conditions, especially in regard to the teaching staff of the different veterinary colleges, might call for some variation, it is generally felt that in some one study some particular instructor shall give in detail and emphasize the importance of the clinical symptoms. It would seem only logical that this should be left to the man teaching clinical medicine. In Therapeutics and Sanitary Science, for example, we see no reason why other than mere mention of the form of parasitism to be dealt with is necessary. The students already have or will have information regarding parasites from their studies in Parasitology. The instructor, for want of time, if for no other reason, must accept the student's information or assume that it will be acquired later; certainly he should not attempt to give it. On the other hand, the time allowed to the study of animal parasites does not permit of a complete and thorough discussion of symptoms, treatment, and prevention, and the man teaching the subject is as a rule not especially prepared to do this. Finally, it seems only logical that this should be dealt with by the teacher of Theory and Practice on the same basis that he would discuss the symptoms, treatment and prevention for other diseases.

The student following his completion of parasitology and of studies such as microbiology, physical diagnosis, therapeutics, and sanitary science should be prepared to take up in theory and practice and clinics every phase of parasitism, and should be able to understand and carry out methods of clinical diagnosis, prevention and treatment.

To summarize, the man teaching parasitology should cover all phases of the subject in more or less detail as outlined above with the exception of the clinical symptoms, treatment and prevention. In the case of the latter the teacher of Parasitology will in many instances find that the symptoms and lesions are so connected and associated that they must be discussed together. Again, prevention is so completely dependent in many cases upon a thorough knowledge of the life history that in order to stimulate the student to the importance of knowing the life history, the fundamental principles of prevention must at least be mentioned. On the other hand, the teacher of the study, Theory and Practice (medicine), should take up and emphasize the *symptoms* of parasitic disease, the *treatment* and *methods* for *prevention* and be held responsible for the final rounding out of the student's knowledge of this phase of the subject; in short he should deal with these points the same as he does with identical points in other diseases. The teacher of Theory and Practice should take up any or all phases of parasitology that may help to make the diagnosis and treatment of individual cases and the handling of outbreaks practical and successful. He should give a general summary of all phases of the subject, and fix the important and essential points in the student's memory so that they will remain forever a usable part of his knowledge of diseases of domestic animals.

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NOTES ON THE GENUS *CATHARINAEA* IN IOWA

LUCY M. CAVANAGH.

The Genus *Catharinaea* is represented in Iowa by mosses which have been referred in all published lists to the species *C. undulata* (L.) W. & M. and *C. angustata* Brid. Both are species of very wide distribution.

C. undulata is a rather well marked species, easily recognized without a microscope. It is found in protected places, usually in woods. So far as noted in Iowa it presents comparatively little variation, which is fully covered by the published descriptions.

The smaller forms of *Catharinaea*, with harsher leaves, have been referred to *C. angustata*. They are usually found in more exposed places, though they are sometimes found associated with *C. undulata*.

The species in this genus are based almost entirely on leaf characters. The two species cited are distinguished by the number and size of the lamellae, by the comparative width of the costa and blade, and by the extent of the serrations on the margin of the leaf.

A third species, with papillose leaves, has been described from Minnesota under the name *C. Macmillani* Holz. The following table shows the distinguishing characters of the three species as given in published descriptions:

	Margin	Width of Costa	No. of Lamellae	Height of Lamellae
C. undulata	Serrate ¾ of length	1/8-1/10 of leaf	2-6	3-6 cells
C. angustata	Above middle only	1/3-1/4 of leaf	5-7	5-8 cells
C. Macmillani			7-10	8-12 cells

In a study of an extensive series of forms referred to *C. angustata* it was found that the variation in the above-noted characters is much greater than is indicated in the table. The observed range of variations is indicated in the following table:

Serrated	Width of Costa	No. of Lamellae	Height of Lamellae	Papillae
1. To middle	¼ of blade	6	6-13 cells	None
2. Below middle	⅓-¼	5	5-9 cells	Trace
3. Below middle	⅓	7-8	4-12 cells	None
4. Below middle	Nearly ⅓	6-10	5-13 cells	None
5. Below middle	More than ⅓	6	9-18 cells	None
6. Below middle	More than ⅓	6-8	5-10 cells	Slight
7. To middle	Nearly ⅓	9	4-8 cells	Slight
8. Three-fourths	About ⅓	7-8	7-13 cells	Distinct

Numbers 1, 2, 3, 6, and 7 are from Johnson county; 4 is from Iowa county; 5 from Louisa county; and 8 from Lee county.

It is evident that the variation in leaf-characters is much greater than the keys and descriptions would indicate. This is especially true of the number and height of the lamellae. The character of the leaf-surface is also a more or less variable quantity. Number 8 is distinctly papillose, and seems to be typical *Macmillani,* but Nos. 2, 6 and 7 also show papillæ more or less distinctly. Of *C. Macmillani* Holzinger says[1] that "this species is at once distinguished by its papillose leaves." Unless some other distinguishing characters can be found it seems that *C. Macmillani* should be referred to *angustata.* Perhaps it might stand as *C. angustata* var. *Macmillani* (Holz.).

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[1] Minnesota Botanical Studies, 1903, No. XII, p. 120.

THE USE OF COMMON NAMES FOR PLANTS

B. SHIMEK

A plea is frequently made by lovers or amateur students of plants for the use of so-called common (or vernacular) names for our species. Sometimes it is voiced also by secondary school teachers of botany, and last year it was included in one of the official reports of this Academy. The writer has received a number of written and verbal complaints aimed at the use of scientific names only, in papers treating of the plants of our state, and every other botanist in the state undoubtedly has had similar experience.

In view of these circumstances it seems worth while to note some of the difficulties which lie in the way of the general use of common names.

No question can successfully be raised against the use of scientific names where accurate designation is demanded. This is especially true in scientific records, and in the naming of plants which possess special properties or qualities making them of value for medicinal, industrial, or other special purposes.

Scientific names possess two great advantages: *First,* they are universal. Botanists of all countries recognize them, and employ them consistently. No matter in what language a scientific botanical paper is written, the plants are designated by scientific names which will be recognized everywhere, at least by systematic botanists.

Second, they are accurate and specific. Even in those cases in which, for various reasons, several scientific names have been applied to the same species the botanist has little difficulty in determining the identity of the species; and the cases in which the same scientific name has been applied to more than one species are so few that they cause but little trouble, and even here the use of the author's name practically removes all doubt.

Common names possess neither of these qualities. From the very circumstance that they are vernacular, there must be at least as many groups of them as there are languages. The common names in one language can mean nothing to people using another, and there would be the same objection to the acceptance of the common names from another language that is made now to the use of the Latinized scientific name. If, then, common names were generally used it would make communication concerning botanical subjects between different countries very difficult, and botany is a subject too broad and of too general interest to be thus hampered.

The demand for the use of common names has been made in all countries and in all languages having a scientific literature, and botanists have usually made an effort to assist those who made the demand by including common names in their descriptive works. Sometimes the result has been rather absurd, as in the case of Dr. Rostafinski's monograph on the Slimemoulds.[1]

In this elaborate and strictly scientific work the author includes "common names," mostly coined by himself, for all the species. Being a loyal Pole, and writing his work in his native tongue, he, of course, uses *Polish* common names, and the "dibliks," "mavoreks," etc., of this author would hardly be more satisfying to the average American than are the scientific names now in use. If, on the other hand, American botanists should coin their own names for these forms, — most of which are common to Europe and America, — the result would be just about as satisfying to the Pole, — and not much more so to the American! The absurdity of the use of common names in such cases is made manifest when we consider that the vast majority of people in any country could not recognize the various more or less obscure species even under the group name "Slimemoulds," or its equivalent, and the designation of these obscure forms by common names could serve no purpose.

A still stronger objection to common names arises from their lack of accuracy and definiteness. The following cases will serve for illustration:

1. Many of the names as commonly used are group names which may be applied to any one of several species, such as Spanish needles, sedges, goldenrods, willows, etc. The attempt to differentiate species by a common name in many of these groups seems scarcely worth while since even experienced botanists often hesitate to determine the species. This is true of most of the cryptogams, and applies quite as well to the more difficult groups of flowering plants, such as the sedges, hawthorns, and others. It would be just as useless to apply common names to the species of these groups as it would be to apply them to all the fossils, to the various species of plant-lice, or to the species of other more or less obscure or difficult groups. Manifestly records and designations made with such indefinite names would have little value.

[1] Rostafinski, Dr. J. T., Monografia Sluzowce; 1875.

2. The same common name is so often applied to different species, even in the same locality, that the application in any particular case leaves one in doubt as to the species intended. A "jack-oak" may be any oak, especially of the black-oak group, for which the user has no other name; the "nut-pine" may be any one of a dozen or more species; the "blue-bell" may be a *Polemonium,* a *Mertensia,* or a *Campanula*; the "crocus" may be a true *Crocus,* but it is quite as likely to be *Anemone patens* var., or *Trillium nivale*; the "cow-slip" may be a *Caltha,* or a *Dodecatheon*; the "honey-suckle" may be a *Lonicera,* an *Azalea,* or an *Aquilegia*; "Indian-tobacco" is *Lobelia inflata* to the pharmacist, but any species of *Antennaria* to almost everyone else; "beggar's-lice" may include almost anything from a *Lappula* or *Cynoglossum* to *Sanicula, Circaea,* and *Agrimonia,* if only the fruit is a little bur, and in the east it may mean a *Bidens*; the "horse-weed" may be *Ambrosia trifida, Erigeron canadense,* or *Iva xanthiifolia*; "dog-fennel" is a *Maruta* in the north, and a *Helenium* in the south; the "adder's-tongue" in one locality is an *Erythronium,* and in another an *Ophioglossum*; the "Christmas-fern" to some is a *Lygodium* and to others a *Polystichum*; and so on through a long list.

The claim that the common name is "easier" than the scientific name does not always hold true. Few people hesitate to designate some of our cultivated plants by such names as Chrysanthemum, Gladiolus, Zinnia, Amaryllis, Narcissus, Asparagus, Spiraea, Catalpa, Salvia, Canna, Begonia, Cosmos, Dahlia, Crocus, etc., and certain native or cultivated plants by such names as Verbena, Phlox, Hydrangea, Anemone, Aster, Clematis, Yucca, Hepatica, Lobelia, Iris, Oxalis, Sassafras, Trillium, etc., yet every one of these names is the scientific name of a genus, and there are many more like them. In a few cases even the scientific specific name is used as a common name, as in the case of oleander (*Nerium oleander*); Japonica (*Cydonia japonica*); and calamus (*Acorus calamus*).

In many cases the common name is but a slight modification of the scientific name, either by the addition of a qualifying adjective, or by a slight change in spelling, as illustrated by the following cases: sweet alyssum (*Alyssum*); perennial phlox (*Phlox*); showy orchis (*Orchis*); gentian (*Gentiana*); rose (*Rosa*); tulip (*Tulipa*); lily (*Lilium*); lupine (*Lupinus*); saxifrage (*Saxifraga*); peony (*Paeonia*); and many others.

Not infrequently, moreover, the scientific name of one species is used as the common name for another. Thus, the name "syringa" is commonly applied to the mock-orange (*Philadelphus coronaria*), but it is the generic name of the lilac; "smilax" is applied to a hothouse *Asparagus,* but it is the generic name of sarsaparilla and the greenbrier; "geranium" is really the spotted cranesbill of our woods, and not the cultivated *Pelargonium* known by that name; "nasturtium" is a *Tropacolum,* but it was formerly the generic name of insignificant plants belonging to the mustard family, now known as *Radicula;* the name "calla" is properly applied to a small native swamp species rather than to the cultivated calla-lily, which is a *Richardia*; etc. Surely it would be no more difficult to use these names correctly than it is to apply them erroneously!

Botanists have made repeated efforts to establish common names by including them in descriptive manuals, but in the great majority of cases they have not been accepted generally, and locally the manuals have been criticised for giving the wrong common name "because it did not conform to the local usage!" Despite all that botanical authors have attempted in the direction of fixing common names, to many people the columbine is still a "honey-suckle," some species of Asparagus are "ferns," and many names are hopelessly confused in common usage. The botanist can scarcely be justly criticised for turning to the scientific name for accurate designation when his own efforts to standardize common names receive such scant attention.

The use of common names will continue, but those who use them should join in some effort at standardization. In the great majority of cases it would probably be best to recognize the common names which have appeared in edition after edition of our descriptive manuals. In many cases, however, it would be better to employ the generic name as the common name. Thus in the sedge family (*Cyperaceae*) it scarcely seems worth while to apply common names to all the species (as has been done in one of the recent manuals) since they are usually so difficult to distinguish, but it would make for greater accuracy if the names of the genera, as *Cyperus, Scirpus, Carex, Eleocharis,* etc., should be adopted as common names of the plants in the several groups. A similar use of generic names could be made in many other cases, especially in the larger families, such as the *Leguminosae, Labiatae, Scrophulariaceae, Compositae,* etc.

To bring about this standardization of common names will require the combined efforts of all who are interested. It is evident that the botanists alone cannot do this, for they have been trying it for a long time — and moreover, the scientific names meet all their wants; it is equally evident that it is not possible to accept all the local common names. This effort must be made in a systematic manner in connection with a more general study of our local floras, both scientific and amateur. Two ways of reaching this result are here suggested:

1. Restore systematic plant study in our high schools. The indoor "laboratory methods" employed in recent years in our secondary schools have failed to develop that deep interest in the living world about us which is of so much importance in scientific work, and which is indispensable in worth-while amateur efforts. The old-time botany, with all its faults (which were no greater than these of modern teaching, and most of which could be eliminated by the proper preparation of teachers), brought our young people in more direct contact with the living world, and gave them something which they could carry into ordinary life without the handicap of laboratory equipment.

This kind of work would present an excellent opportunity for the more general use of standardized common names.

2. Encourage the amateur study of local plants by members of existing organizations, or by societies organized for the purpose, in much the manner in which the Audubon societies have carried on the study of birds. If necessary, organize Asa Gray clubs, or encourage such study in connection with the conservation efforts which are now being made by so many organizations. Teach our young people to study our local plants without destroying them. Many of the old-time students of birds thought it necessary to kill the bird to be studied, but today greater interest is taken in the study of the living bird. So, many who consider themselves students and lovers of plants destroy them; they should be taught that greater satisfaction comes from the study and enjoyment of plants which are left undisturbed for repeated observations.

The greater interest in, and knowledge of, plants resulting from such organized effort will make it necessary to employ recognized common names more freely, making the knowledge of them more general, and their use consequently more accurate and more consistent.

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THE GENUS *CEANOTHUS* L. IN IOWA

B. SHIMEK

The low shrubs known as New Jersey Tea, belonging to the Genus *Ceanothus*, were once very abundant throughout Iowa, occurring chiefly on the prairies, and sometimes in dry, open woods and along the borders of drier thickets. On account of their long, tough roots they interfered with the breaking of the prairie, and the commoner species, *C. americanus*, known as "shoestring" or "red-root," was by no means popular with the pioneers. Perhaps for this reason, and because they were so common, these attractive shrubs were seldom cultivated in this state.

In more recent years, however, as the native plants became rarer, their cultivation has increased, especially eastward. Their conspicuous dense clusters of small white flowers and their not unattractive foliage, together with their hardiness, make them very desirable for this purpose. As the forms in our state are very variable, and also differ somewhat in habit and distribution, a discussion of them should interest both the amateur lover and the scientific student of plants.

The Genus *Ceanothus*, as now recognized, is wholly American. Related species from other parts of the world are now placed in other genera. In 1753 Linné[41]* recognized but three species, of which only one, our *C. americanus*, is now retained in the genus. The same species were listed by Aiton[1] in 1789, but in 1811 he[2] increased the number to five, of which three are now placed in other genera. In 1825 DeCandolle[20] recognized forty-one species, but he included a dozen species now placed elsewhere. In 1867 Bentham and Hooker[9] placed the number of species at about twenty-eight; Parry[53] listed thirty-three North American species in 1889; in 1896 Engler and Prantl[23] credited North America with thirty-six species; while in 1905 Britton[11] placed the number at about thirty-five for North America. Up to 1913 the Kew Index and Supplements[37] enumerated sixty-eight species, which probably are not all valid.

The great majority of the species are found in the dry sections

* The superior figures throughout refer to the numbers in the Bibliography at the close of this paper.

of the western part of our country and northern Mexico. In Iowa two species and a variety have been recognized. Like all other members of the genus these forms are very variable, and in consequence there is much confusion in the descriptions, and in the definition and recognition of species. A discussion of these differences and variations, so far as they concern the Iowa species, is here presented.

The three forms found in Iowa are: *Ceanothus americanus* L., *C. ovatus* Desf., and *C. ovatus pubescens* T. & G.

I. *Ceanothus americanus* L. Pl. VIII, fig. 1, a to i; l to p.

This is the larger species, once common on the prairies, especially in the eastern part of the state, but now most commonly preserved in dry, open woods and oak openings. This species is variable both in form and structure of some of its parts and in habit, but it may usually be readily recognized by its broad, soft, often subcordate leaves, the elongated stalk of the flower cluster, the usually clustered stems, and the larger, lighter-colored smooth seeds. The flower cluster is also usually more elongated than in the following species, and the flowers appear later.

A comparison of published descriptions and observations on our Iowa material shows that practically the entire range of variation in this species is exhibited in the Iowa representatives. The leaf is the most variable part of the plant and a more detailed discussion of its characters is worth while.

Form. — The form of the leaf is variously described in the books as ovate [4 21 22 25 26]; ovate or oblong-ovate [13 15 31 40 71 72 74 76]; oblong-ovate [18 19 77]; obovate or oblong-ovate [32]; heart-ovated [10]; and ovate or ovate-lanceolate, rarely orbicular ovate [68].

The most common Iowa forms vary from oblong, through oblong-ovate to ovate, but the larger leaves on most plants are often cordate-ovate or even cordate. Occasionally the leaves, especially the later ones, are narrowly oblong or ovate-lanceolate, and still less frequently broadly oval or nearly orbicular leaves occur.

Base. — The base of the leaf has been described as rounded or rarely acutish, or sometimes a little cordate [72]; abruptly narrowed or subcordate [68]; sometimes unequal or slightly cordate [18 71]; obtuse or subcordate [11 13]; often slightly heart-shaped [31 32]; and acute or sometimes slightly cordate [71].

The Iowa specimens show much variation in the form of the base, often on the same plant. They are rather rarely narrowly acute at base, but more frequently vary from broadly or abruptly acute through obtuse or rounded, to subcordate, or rarely quite cordate.

Apex. — The apex of the leaf is by no means uniform. It has been described as usually acute [4]; acute or acutish or rarely acuminate [68]; acute or acuminate [11 13 32]; acuminate [10 18 19 21 22 26 71 72]; and acute or slightly acuminate or obtusish [72].

Iowa specimens vary from short-acuminate through sub-acuminate to acute, somewhat obtuse, distinctly obtuse or rounded. Few distinctly acuminate forms occur. The apex is often very variable in the leaves of the same plant. The same thing, however, is also true of the other leaf characters.

Margin. — The margin of the leaf is represented as serrate [11 13 18 21 26 32 40 71 72 74 76]; finely serrate [10 30]; finely and irregularly serrate [4]; and toothed [68].

Most of the Iowa leaves are sharply, often finely serrate near the base, and serrate-dentate, serrate-crenate, crenate-dentate, or dentate towards the apex. Sometimes the teeth are quite irregular, and in all cases at least the younger leaves have the teeth black-tipped.

Surface. — The surface of the leaf is exceedingly variable. It has been described as more or less villous pubescent [74]; very downy with soft hairs beneath [77 78]; finely pubescent, especially beneath [12]; more or less pubescent [31 32]; downy beneath [30]; somewhat pubescent [26]; pubescent beneath [19 21]; pubescent — tending to become glabrous with age [68]; nearly glabrous above, canescently tomentose beneath [72]; nearly smooth above, more or less velvety pubescent underneath [71]; pubescent beneath; upper nearly smooth; nerves quite hairy beneath, more or less ferruginous [18]; bright green and dull above, paler and pubescent or nearly glabrous beneath [4].

The Iowa specimens exhibit equal variation. Some are densely pubescent on the lower surface, with short scattered loose or appressed hairs above; others have the lower surface densely pubescent while the upper is quite glabrous; still others are pubescent below, and on veins, only, above; and still others are glabrous above and pubescent only on the veins below. The young leaves are usually quite densely pubescent, but they often become nearly or quite glabrous above as they mature.

Size. — The size of the leaf is also very variable, commonly on the same plant. The length of the blade is variously recorded as 1 to 3 inches [13]; 1½ to 3 inches [4]; 1½ to 2½ inches [74]; 2 to 3 inches [10 71 72]; 2 to 4 inches [18]; 2.5 to 7.5 cm.[11]; 3.5 to 6.5 cm.[15]; 3 to 10 cm.[68]. The width is given as follows: ½ to 1 inch [13]; 1 inch [10]; 1 to 2 inches [18]; 1.25 to 2.5 cm.[11]; 2.4 to 5.5 cm.[32].

Several hundred Iowa specimens were examined. They show a maximum length of 12.1 cm., and a maximum width of 6.4 cm. The leaves on our plants vary much in size, those on the upper parts of the stem and branches being quite small, often falling much below the minimum in the published descriptions.

The petiole. — The length of the petiole is variously given as from ⅙ to ½ an inch, or 4 to 12 mm. In the Iowa specimens the length varies from 2 to 13 mm., the usual length being about 4 to 6 mm.

Habitat. — This species is assigned to a great variety of habitats in the published descriptions. It is credited to woods [25]; woods and groves [77 78]; woods, sunny places [29]; woodlands and thickets [19]; growing in shade [3]; low pine woods [38]; sandy woods [6 7]; open woods [24 27]; dry woodlands [31]; dry woods [4 44 76]; dry open woods [11 13]; dry woods and copses [71]; copses [34]; dry woodlands and gravelly slopes[32]; dry open woodlands and along river banks[43]; dry open woods and fields in sterile soil[14]; dry woods and on hillsides[68]; barrens [77 78]; meadows and thickets [54]; upland woods and prairies [26]; dry woodlands and prairies [5]; prairies and open woods [35]; prairies and forest-border [63]; prairies and edge of woods [47 48 63 66]; half-wooded prairie hills and even on prairie, but more frequently at the thicket edge near the bur-oak clumps [42]; dry grounds [29]; dry hills [68]; higher slopes and drier places [61]; on hills [57]; loess hills [50 65]; dry gravelly hills [45 66]; in dry places, along roadsides, on prairies, etc.[62]; prairie openings [64]; prairies [28 34 49 51 52 66 75]; dry prairie [16]; highland prairie [70]; dry prairies and ridges [33 63]; sand and prairie[67]; sand and gravel [64]; sandy shores and dunes [66 67]; and simply as xerophilous [46].

While frequently reported from woods even in Iowa, this species was here primarily a prairie plant. The general cultivation of the prairie has destroyed much of its former habitat, and it is now found only on the scattered remnants of the unbroken prairie, in open places in upland woods, and in a few places on sand and gravel. It does not occur in deep woods, but is sometimes found in places which are quite well shaded during at least a part of the day. In such places it grows taller, more spindly, with weaker stems, looser flower clusters, and larger and thinner leaves. The specimens with the finest, most compact and abundant flower clusters, are found quite in the open here in Iowa. The species is essentially xerophytic, though somewhat less prominently so than the variety of the following species.

The flowers are usually at their best during the last week of June and the first week of July, but occasional specimens may be found in flower in the southern half of the state as early as the first week in June, and in the northern part as late as the second week of August.

This species is distributed throughout the state, and no doubt originally occurred in every county of the state. It is (and was) more common, however, in the eastern half of the state, and here now more frequently occurs in open woods. In the western part of the state it is largely displaced by the variety of the following species, particularly on drier knolls, etc.

New Jersey Tea is worthy of cultivation, and should be grown in rather light soil, in well-drained and preferably open places, though it will stand some shade. It may be propagated from seeds or cuttings. The great extent of the roots, especially if growing in open places, makes it difficult to transplant larger plants.

2. *Ceanothus ovatus* Desf. Pl. VIII, fig. 1, j, k.

This species and its variety may be distinguished from the preceding species by the following characters: the stems are usually single, not clustered; the leaves are smaller, narrower, never cordate at base, and thicker; the flower clusters are usually shorter and on shorter stalks; and the seeds are usually dark brown, distinctly marked with shallow, irregular pits, and their length does not exceed 2 mm. The seeds of *C. americanus* are more than 2 mm. long, light brown in color, and usually shiny and without pits. Only a few seeds of the latter have been observed with pits, and these appeared in most of them on only a part of the surface. These seeds were obtained from the most vigorous plants of the species which the writer has seen in Iowa, and were collected in upland woods, rather open, near McGregor. These seeds were 3 mm. in length. Immature seeds of both species are likely to be grayish, or grayish-brown.

The typical form of *C. ovatus* is quite rare in Iowa. It has been reported from several counties of the state, but in the majority of cases the plants belong to the following form, which has been recognized as a variety. The writer's own observations in all parts of the state convince him that the type is not common in Iowa, and that the variety is by far the more common representative of the species, especially in the western part of the state. The variety does not occur in the eastern part of our country so far as references at hand indicate. To avoid confusion with the variety, eastern authors are chiefly cited in the following discussion of the type form.

This species also represents a wide range of variation, especially in the character of the leaf, as is shown in the following summary of references and characters.

Form. — Eastern and southeastern authors describe the leaves as narrowly oblong to elliptic, oval or ovate [68]; oblong to oval or ovate [59]; oval, elliptical, sometimes oblong [10]; oval [21]; narrow-oval, or lance-oblong [30]; narrowly oval or elliptical lanceolate [74]; elliptic to elliptic-lanceolate [4]; oblong or oval-lanceolate [13]; oval-lanceolate [77]; oval-lanceolate or narrowly oblong [78]; narrowly oblong or elliptical lanceolate [71, 72]; narrowly oval or elliptical lanceolate [31, 32, 40]; oval to linear-oblong [71]; oval to almost linear, never ovate [71, 72].

Iowa specimens, collected near Winterset and New Albin, have leaves varying from oblong to oblong-ovate, lance-ovate, and lanceolate, thus practically covering the entire range of variation in form as presented in the published descriptions.

Base. — The base is variously described as acute [71]; mostly acute [77, 78]; acute or rounded [66]; and mainly obtuse [11, 13].

The Iowa specimens noted above vary from acute to broadly acute and sub-obtuse.

Apex. — The apex of the leaf is defined as acute, sometimes obtuse [71, 72]; mostly acute [77, 78]; mainly obtuse, sometimes acute [11, 13]; obtuse or sub-acute [10]; obtuse or acutish [68]; and obtuse or rounded [32].

The apex of the Iowa specimens varies from acute to sub-acute, narrowly obtuse, and obtuse.

Margin. — The margin of the leaf is described as serrate [10, 11, 12, 13, 21, 68]; finely glandular serrate [31, 32, 40]; serrulate [71, 72]; crenately serrate [10, 77, 78]; and crenulate-serrate. All agree that the teeth are gland-tipped, and several define them as black [10, 71, 77, 78].

The Iowa specimens are serrate towards the base and crenulate-serrate, or crenate-serrate, towards the apex.

Surface. — As the distinction between the species and variety is based wholly on the character of the surface, especially of the leaves, the following published descriptions of the surface of the leaf are of especial interest. It is described as smooth, never pubescent beneath [21 22]; nearly glabrous, glossy above [4]; nearly glabrous [11 72]; glabrous to nearly so [31 32]; nearly smooth [8]; lower surface glabrous or with few scattered hairs, nearly glabrous [68]; nearly glabrous or somewhat pubescent [74]; veins pubescent beneath; smooth and shining [76 77 78]; veins slightly pubescent underneath; sometimes lower surface covered with glands [10]; pubescent when young; at length nearly or quite smooth, except the slight pubescence on veins underneath [71]; glabrous, or with few hairs on principal veins; nearly glabrous throughout, or W. races densely pubescent [12 13]. The last-mentioned western races are the variety *pubescens*!

In the Iowa specimens the upper surface of the leaf is glabrous, or very nearly so, occasionally with a few inconspicuous short scattered hairs. The lower surface is sometimes slightly pubescent, the pubescence being almost wholly on the veins, and quite inconspicuous. Very young leaves are more or less brown-pubescent but the upper surface soon becomes green and more or less shiny.

Size. — The size of the leaf as given in the various descriptions varies from 1 to 3 inches (1.5 to 7.5 cm.) in length, and from ¼ to ¾ of an inch (6 to 18 mm.) in width.

The Iowa leaves vary from 3.0 to 7.2 cm. in length, and from 1.2 to 3.4 cm. in width.

The great variation in characters has resulted in efforts to recognize varieties, and several have been named but they are of little interest here in Iowa, as they are mostly southern or eastern, or of little significance.

Habitat. — Western references to habitat probably apply in large part to the variety. In the references which manifestly apply to the typical form the habitat is given as follows: Rocks [30]; dry rocks [31]; dry rocks or sandy soil [32]; barren rocky places [71 72]; on dry gravelly banks [45]; sandy shores [55]; sandy soil [68]; rocky places and on prairies [12, 13]; knolls in the rolling prairie [39]; and shade [3].

The most typical Iowa forms were found in open places on rocky slopes — rarely on the prairie. The typical form resembles the variety when the leaves and shoots are quite young, but at maturity the shiny green, glabrous, or nearly glabrous, upper surfaces of the leaves, and the scant pubescence elsewhere, give the plant a strikingly different aspect.

This species may be cultivated in much the same manner as the preceding form. It is not easily obtained in Iowa, however, and the other forms are quite as suitable.

3. *Ceanothus ovatus pubescens* T. & G. Pl. VIII, fig. 2, a-o. The standing of the form with the persistent pubescence on the leaves, peduncles and twigs has been more or less in dispute. Long ago Torrey and Gray [72] recognized a variety to which later the name *pubescence* was given. The leaves, especially on the veins, the young branches, and the peduncles, are pubescent, and the leaves are usually smaller and the pubescence ferruginous. This describes very well the commoner form in Iowa. More recently this form has been assigned the rank of a species by several authors [17 58 59 68]. On the other hand, other authors do not even recognize the variety, but consider all the forms under the specific name *ovatus* [13].

Surface. — The flowers and flower clusters, the seeds, and the form, base, apex, margin, venation and petiole of the leaf of this form agree with the type, presenting the same variations and offering no mark of distinction. None of the authors consulted, who describe both the species and the variety, make mention of these characters, but they place the emphasis on the surface of the leaves, and sometimes on the peduncles and twigs. The published references to this character show some differences, but all agree that more or less pubescence persists on both surfaces of the leaf, that on the lower being more copious. The various authors describe the surface of the leaf as pubescent [72]; densely pubescent [11 12 13]; copiously and permanently pubescent beneath [68]; permanently sordid-tomentose [32]; glabrate except the veins above; villous beneath [60].

Iowa specimens show considerable variation in the amount of pubescence, but the great majority are readily referable to this variety, for even the fully matured leaves retain much of the pubescence. Speciments from Lyon, Harrison, and Shelby counties have leaves densely pubescent on both surfaces, but in the great majority of cases the lower surface is quite densely pubescent (the pubescence being chiefly on the veins), while the upper surface is provided with straighter hairs, which may be scant and scattered, or quite crowded. The twigs and peduncles in all cases retain much of the dense pubescence until late in the season. The pubescence is usually brownish or rusty, but sometimes almost white.

Form. — In form the leaves of Iowa specimens are usually oblong or oblong-ovate, but they vary from broadly oblong, to oblong-ovate, obovate, oblanceolate, oblong-lanceolate, linear-lanceolate, and linear-oblong.

Base. — The leaf base is also somewhat variable, though it is usually acute or sub-acute. It varies, however, to obtuse and rounded, but is never cordate.

Apex. — The apex is most frequently somewhat acute, or sub-acute, but varies from short-acuminate to obtuse or rounded.

Margin. — The margin is usually somewhat irregularly toothed, usually being serrate nearer the base and dentate or crenate towards the tip. It varies, however, from serrulate or crenulate to serrate, dentate, crenate, serrate-dentate, or crenate-dentate.

Size. — The blade of the leaf reaches a maximum length of 9.2 cm., but is usually 4 or 5 cm. long. The width reaches 4.9 cm., but more commonly it is about 2 cm. The petiole is usually about 1 cm. long, but varies from .2 cm. to more than 2.0 cm.

Habitat. — The habitat of the variety has been described as follows: sand-hills [57 58]; sandy soil [59]; stony hillsides [49]; gravelly slopes [65]; dry hills [35]; loess ridges [65]; hillsides and in dry soil [68]; dry prairie ridges [33 63]; dry prairie [63]; prairie [57 65]; prairie and forest border [63]; open thickets [17]; wooded bluffs [57].

In Iowa the variety is found most commonly on dry prairie knolls or ridges, but also occurs in prairie openings on partly wooded hillsides.

The writer has collected this form in all parts of the state excepting the southeast quarter, but it is much more common in the western part of the state. Eastward in the state it is extremely local.

Both the type and variety usually flower in Iowa in the third or fourth week of May, though a few plants have been found in flower as late as the middle, and in one case even the end, of August. In any locality where both *C. americanus* and *C. ovatus* or the variety occur, the former will flower from three to four weeks later. Because of this circumstance, if for no other reason, the two species probably seldom, if ever, hybridize.

While there may be some doubt as to the validity of this form as a species or variety, it is ordinarily quite distinct, and the peculiarity of distribution makes it desirable to retain the name for ecological records. It is certain that the vast majority of Iowa plants belong to the variety rather than the type.

The writer had the privilege of examining the extensive set of *Ceanothus* in the collections of the Missouri Botanical Garden, St. Louis, and he found that all the eastern and southeastern forms of this species belong to the type, while the western and southwestern forms belong to the variety *pubescens.*

This variety is drought-resisting, and may be planted to advantage in dry places. It should be propagated like *C. americanus,* but it should be planted in open places.

The Iowa material herein discussed is deposited in the herbarium of the State University of Iowa.

BIBLIOGRAPHY

(The numbers correspond to those in superior type in the text.)

1. Aiton, Wm., Hortus Kewensis, Vol. 1, p. 70; 1789.
2. Aiton, Wm., Hortus Kewensis, 2nd ed., Vol. II, p. 22; 1811.
3. Apgar, A. C., Ornamental Shrubs of the United States, p. 99; 1910.
4. Bailey, L. H., Cyclopedia of American Horticulture, Vol. I, p. 264; 1904.
5. Barnes, W. D., Reppert, Ferd, and Miller, A. A., The Flora of Scott and Muscatine Counties, Proc. of the Davenport Academy of Sciences, Vol. VIII, p. 211; 1900.
6. Beal, W. J., Michigan Flora, Fifth Report of the Michigan Academy of Science, p. 99; 1904.
7. Beal, W. J., and Wheeler, C. F., Michigan Flora, 30th Annual Report of the Secretary of the State Board of Agriculture, p. 80; 1892.
8. Beck, L. C., Botany of the U. S. North of Virginia, 2nd ed., pp. 70-71; 1856.
9. Bentham, G., and Hooker, J. D., Genera Plantarum, Vol. I, pp. 378-379; 1867.
10. Bigelow, Jacob, Florula Bostoniensis, 2nd ed., p. 92; 1824.
11. Britton, N. L., Manual of the Flora of the Northern United States and Canada, 2nd ed., p. 613; 1905.
12. Britton, N. L., and Brown, A., Illustrated Flora of the Northern U. S., Canada, and the British Possessions, Vol. II, p. 407; 1897.
13. Britton, N. L., and Brown, A., Illustrated Flora, etc., 2nd ed., pp. 504-505; 1913.
14. Committee of the Connecticut Botanical Society, State Geol. and Natural Hist. Survey, Bulletin No. 14, p. 275; 1910.
15. Coulter, J. M., Botany of Western Texas, Contributions from the U. S. National Herbarium, Vol. II, No. 1, pp. 60-61.
16. Cratty, R. I., Flora of Emmet County, Iowa, Proc. of the Iowa Academy of Sciences, Vol. XI, p. 233; 1904.
17. Daniels, Francis P., The Flora of Columbia, Missouri, and Vicinity, The University of Missouri Studies, Science Series, Vol. I, No. 2, pp. 42-67.
18. Darlington, Wm., Flora Cestrica, p. 148; 1837.
19. Darlington, Wm., Flora Cestrica, 3rd ed., p. 49; 1853.
20. DeCandolle, A. P., Prodromus, etc., Vol. II, pp. 29-31; 1825.
21. Eaton, Amos, Manual of Botany for North America, 6th ed., p. 85; 1833.
22. Eaton, Amos, and Wright, John, North American Botany, 8th ed., p. 185; 1840.
23. Engler, A., and Prantl, Karl, Die Natürlichen Pflanzenfamilien, III Teil, Abt. 5, p. 413; 1896.
24. Fink, Bruce, Spermatophyta of the Flora of Fayette, Iowa, Proc. Iowa Acad. Sci., Vol. V, p. 86; 1897.
25. Fitzpatrick, T. J., Notes on the Flora of Northwestern Iowa, Proc. Iowa Acad. Sci., Vol. V, p. 112; 1898.
26. Fitzpatrick, T. J., Manual of the Flowering Plants of Iowa, Part I, p. 29; 1899.
27. Fitzpatrick, T. J. and M. F. L., Flora of Southern Iowa, I., Proc. Iowa Acad. Sci., Vol. V, p. 140; 1898.

28. Fitzpatrick, T. J. and M. F. L., Flora of Southern Iowa, II., Proc. Iowa Acad. Sci., Vol. VI, p. 180; 1899.
29. Geiser, Samuel W., Bull. of Upper Iowa University, Biological Series, No. 2, p. 12; 1918.
30. Gray, Asa, Field, Forest and Garden Botany, revised by L. H. Bailey, p. 106; 1895.
31. Gray, Asa, Manual of the Botany of the Northern U. S., 6th ed., p. 112; 1890.
32. Gray, Asa, New Manual of Botany, revised by B. L. Robinson and M. L. Fernald, 7th ed., p. 562; 1908.
33. Greene, Wesley, Plants of Iowa, Bulletin of the Iowa State Horticultural Society, p. 191; 1907.
34. Hayden, Ada, Notes on the Floristic Features of a Prairie Province in Central Iowa, Proc. Iowa Acad. Sci., Vol XXV, p. 376; 1919.
35. Hitchcock, A. S., A Catalogue of the Anthophyta and Pteridophyta of Ames, Iowa, Contributions from the Shaw School of Botany, No. 7, p. 489; 1891.
36. Holzinger, J. M., List of Plants Collected by C. S. Sheldon and M. A. Carleton in Indian Territory in 1891, Contributions from the U. S. National Herbarium, Vol. 1, p. 190; 1896.
37. Jackson, B. Daydon, Index Kewensis, Vol. I, p. 464; 1895. Supplements: 2nd, 1904; 3rd, 1908; 4th, 1913.
38. Kearney, Thos. H., Report on a Botanical Survey of the Dismal Swamp Region, Contributions from the U. S. National Herbarium, Vol. V, p. 533; 1901.
39. Kellerman, W. A., The Fourth State Catalogue of Ohio Plants, p. 32; 1899.
40. Kellerman, W. A., Gleason, H. A., and Schaffner, J. H., Spring Flora, p. 93; 1906.
41. Linné, C., Species Plantarum, p. 195; 1753.
42. Macbride, Thos. H., Forestry Notes for Dubuque County, Iowa Geol. Survey, Vol. X, p. 632; 1900.
43. MacMillan, Conway, The Metaspermae of the Minnesota Valley, Geol. and Natural Hist. Survey of Minnesota, Botanical Series I, pp. 355-356; 1892.
44. MacMillan, Conway, Minnesota Plant Life, Geol. and Natural Hist. Survey of Minnesota, Botanical Series III, p. 319; 1899.
45. Macoun, John, Catalogue of Canadian Plants, Part I, Geological Survey of Canada, pp. 95-96; 1883.
46. Mohr, Chas., Plant Life of Alabama, Contributions from the U. S. National Herbarium, Vol. VI, pp. 88, 610; 1901.
47. Mueller, H. A., Shrubs and Trees of Madison County, Proc. Iowa Acad. Sci., Vol. VIII, p. 199; 1901.
48. Mueller, H. A., A Preliminary List of the Flowering Plants of Madison County, Proc. Iowa Acad· Sci., Vol. XI, p. 264; 1904.
49. Oleson, O. M., and Somes, M. P., A Flora of Webster County, Iowa, Proc. Iowa Acad. Sci., Vol. XIII, p. 46; 1906.
50. Pammel, L. H., Notes on the Flora of Western Iowa, Proc. Iowa Acad. Sci. Vol. III, p. 115; 1896.
51. Pammel, L. H., Flora of Story County, Iowa Geol. Survey, Vol. IX, p. 242; 1899.
52. Perry, C. C., In D. D. Owen's Report on the Geol. Survey of Wis., Iowa and Minn., p. 610; 1852.
53. Parry, C. C., The North American Genus *Ceanothus* L., Proc. Davenport Acad. Sciences, Vol. V, pp. 162-174; 1889.
54. Peck, Morton E., The Flowering Plants of Hardin County, Proc. Iowa Acad. Sci., Vol. XII, p. 222; 1905.
55. Perkins, Geo. H., A General Catalogue of the Flora of Vermont, p. 11; 1882.
56. Peterson, N. F., Flora of Nebraska, p. 152; 1912.

57. Pound, Roscoe, and Clements, F. C., The Phytogeography of Nebraska, 2nd ed., pp. 91, 127, 146, 233, 358-359, 363; 1900.
58. Rydberg, P. A., Flora of the Sand Hills of Nebraska, Contributions from the U. S. National Herbarium, Vol. III, p. 152; 1895.
59. Rydberg, P. A., Flora of Colorado, Bull. of the Agric. Exp. Sta., Colorado Agricultural College, p. 228; 1906.
60. Rydberg, P. A., Flora of the Rocky Mountains and Adjacent Plains, p. 555; 1917.
61. Shimek, B., The Flora of Lyon County, Iowa, Iowa Geol. Survey, Vol. X, p. 164; 1900.
62. Shimek, B., The Native Shrubs of Iowa, Report of the Iowa State Horticultural Society, Vol. 38, p. 467; 1904.
63. Shimek, B., The Plants of Winneshiek County, Iowa Geol. Survey, Vol. XVI, pp. 154, 193; 1906.
64. Shimek, B., Prairie Openings in the Forest, Proc. Iowa Acad. Sci., Vol. XVII, p. 18; 1910.
65. Shimek, B., Botanical Report, Geology of Harrison and Monona Counties, Iowa Geol. Survey, Vol. XX, p. 434; 1910.
66. Shimek, B., Plant Geography of the Lake Okoboji Region, Bull. from the Laboratories of Natural Hist., State University of Iowa, Vol. VIII, No. 2, p. 34; 1915.
67. Shimek, B., Sand Flora of Iowa, Bull. Lab. Nat. Hist., State Univ. of Iowa, Vol. VII, p. 17; 1917.
68. Small, J. K., Flora of the Southeastern U. S., p. 751; 1903.
69. Somes, M. P., Notes on the Flora of Johnson County, Iowa, Proc. Iowa Acad. Sci., Vol. XX, p. 71; 1913.
70. Todd, J. E., The Ligneous Flora of Southwestern Iowa, The Valley Naturalist, Vol. I, No. 6; 1878.
71. Torrey, John, A Flora of the State of New York, Vol. I, pp. 144-145; 1843.
72. Torrey, John, and Gray, Asa, A Flora of North America, Vol. I, pp. 264-268, 686; 1838-1840.
73. Ward, Lester F., Guide to the Flora of Washington and Vicinity, Bull. U. S. National Museum, No. 22, pp. 72, 155; 1881.
74. Watson, Sereno, Revision of the Genus *Ceanothus*, Proc. Am. Acad. of Arts and Sciences, Vol. X, pp. 333-334; 1875.
75. Webber, H. J., Catalogue of the Flora of Nebraska, pp. 37, 122; 1890.
76. Wood, Alphonso, The American Botanist and Florist, Part IV, p. 77; 1870.
77. Wood, Alphonso, Class-book of Botany, 35th ed., p. 217; 1854.
78. Wood, Alphonso, Class-book of Botany (Revised), p. 291; 1876.

EXPLANATION OF PLATE VIII

Fig. 1 — *Ceanothus americanus* L. a to i and l to p.

a. to b. Seven leaves from same plant; open woods; West Lake Okoboji.
c. A leaf from plant on dry hill-top; McGregor.
d. A leaf from sandy prairie; Muscatine county.
e. Two leaves; open hillsides; New Albin.
f. to g. Three leaves; open hillsides; McGregor.
h. to i. Five leaves; prairie; Mapleton.
l. to m. Four leaves; prairie opening; Decorah.
n. Three leaves; open prairie; Roland.
o. A leaf; prairie opening; Allamakee county.
p. A leaf; open prairie; Nora Junction.

Ceanothus ovatus Desf. j, k.

j. Three leaves; open hillsides; New Albin.
k. Three leaves; prairie opening; Unionville.

Fig. 2. — *Ceanothus ovatus pubescens* T. & G.

a. to b. Eleven leaves from same plant; dry prairie hill; Decorah.
c. Two leaves; prairie; Harlan.
d. A leaf from loess prairie; Missouri Valley.
e. to f. Nine leaves from same plant; prairie; near W. Lake Okoboji.
g. A leaf from high dry prairie; Missouri Valley.
h. Two leaves; high dry prairie; Shelby county.
i. A leaf from open hillside; Decatur county.
j. Three leaves, from high loess prairie; Shelby county.
k. A leaf from rolling prairie; Logan.
l. A leaf from very dry loess prairie; Missouri Valley.
m. Two leaves, from rolling prairie; Shelby county.
n. A leaf, from very high, dry prairie; Harrison county.
o. A leaf from prairie opening; near Winterset.

Fig. 1.

Fig. 2.

DR. RUDOLPH GMELIN

Copy by Mr. Richardson

DR. RUDOLPH GMELIN AND HIS COLLECTION OF MINNESOTA, WISCONSIN AND IOWA PLANTS

R. I. CRATTY

Through the kindness of Mr. Henry C. Gmelin of Elkader, Iowa, a collection of dried plants numbering two hundred and sixty-nine species which were collected by his father, Dr. Rudolph Gmelin, in southeastern Minnesota, western Wisconsin and northeastern Iowa, between the years 1874 and 1894, were presented to the Iowa State College. It fell to the lot of the writer to arrange and mount the collection, and because of the prominence of the collector and the unusual care taken in preparing and preserving the specimens, it has been thought proper to place on record a short biographical sketch of Dr. Gmelin and append a list of the plants.

When, as in the present case, such painstaking care is shown in pressing the plants, straightening out the leaves, selecting good typical specimens and so forth, it is truly a labor of love to identify, mount and distribute in the herbarium, instead of a vexation of spirit as is sometimes the case. Not many of the plants had been named, except those possessing medicinal value, in which he as a practicing physician was more especially interested, as he compounded many of his medicines himself, from barks and roots.

Through the courtesy of his son, Henry C. Gmelin of Elkader, in sending to Dr. Pammel some notes regarding his father's life, the writer is enabled to present this brief biographical sketch.

Dr. Rudolph Gmelin, born at Darmsheim, Wurtemburg, Germany, October 30, 1831, was the son of Rev. Heinrich Gmelin and Christina Louise (Pfeiderer) Gmelin. He graduated from the University of Tuebingen in medicine and surgery April 19, 1854, after which he studied in the Royal Medical College of Wurtemburg, and then went to Vienna, Munich and Prague, spending a year at each place studying and practicing in the hospitals. Several years following were devoted to the practice of his profession in Europe, a part of the time with the German army as he was a volunteer surgeon during the Franco-Prussian war. He was married August 16, 1872 to Miss Sophia Alt, and came to America, October 29, 1873.

The first seven years after coming to this country were spent in practicing his profession at Chicago, Milwaukee, St. Paul, St. Cloud, Minnesota, Lincoln, Nebraska, and Guttenberg, Iowa. He went to Elkader, Iowa, in 1879, and remained there about six months; then for some time he lived in Fountain City and La Crosse, Wisconsin, and Garnavillo, Iowa. In January, 1888, he returned to Elkader where he practiced till his death, August 3, 1909.

Dr. Gmelin became an American citizen in 1884, receiving his naturalization papers in Sterns County, Minnesota, September of that year. To him and his wife, who is still living, and is spending her declining years with her youngest son in Elkader, were born three sons: Robert, who died at the age of eight; Max, born at St. Cloud, Minnesota, in 1875 and now located at Clinton, Iowa, where he teaches music in Wartburg College; and Henry C., born at Guttenberg, Iowa, in 1877, and now in the job-printing business in Elkader.

The following appreciation of Dr. Gmelin is from the columns of the *Register and Argus*: "Dr. Gmelin was of a high type as to mind and character, always a student, he was a lover of nature, of science, of literature and of music. The flowers were his friends; he loved them and he knew every wild flower of the woods and fields and what healing or poisonous property it had. During his later years chess became the recreation of his active mind, the complex problems of that game affording him keen enjoyment.

In religion Dr. Gmelin was a Protestant. He was of a retiring disposition, and instead of the noise and bustle of the streets, preferred that close communion with nature in forest and field and garden, which occupied much of his time when he was not busy in his profession. He loved gardening very much, and by judicious planting, provided his family with an abundance of fresh vegetables throughout the growing season."

The name Gmelin is a celebrated one in the annals of German science, several generations of the family having been prominent in botany, chemistry, medicine and theology. A large number of them devoted their lives to botany, either as collectors, teachers or in research work. Among these may be mentioned George John Gmelin who studied and collected Siberian plants from 1733-1743 upon which is based his *Flora Siberica,* published in 1747-

69; Philip Frederick Gmelin (1721-1768) published numerous works as did John Frederick Gmelin (1748-1804) who was a noted professor at Tuebingen and Goettingen. Ferdinand Gotlob Gmelin (1782-1848) was a professor at Tuebingen and the author of *De Plantarum Exhalationibus*. Carl Christian Gmelin, physician to Carlsrhue, published a work on ferns in 1784. Christian Gotlob Gmelin (1792-1860) was a chemist and botanist at Tuebingin. Samuel Gottlieb Gmelin traveled and made extensive collections of plants in south Russia and the Caspian Sea region. P. Gmelin published in 1867 a systematic work reviewing the system of Jussieu, De Candolle and Eudlicher. W. Gmelin of Stuttgart was also well known as a botanical collector, several specimens of his collection being in the writer's herbarium. The Linnaean genus *Gmelina*, a verbenaceous genus of some eight species of southeastern Asia, Malay Archipelago and tropical Australia commemorates the name, while *Lithospermum Gmelini* (Michx.) Hitch., which is now the accepted name of the *L. hirtum* of Lehmann, a common Iowa plant, commemorates the work of an early collector in this country. Dr. Gmelin's collections in the three states previously mentioned were made as follows: St. Cloud, Minnesota, 1874-5; St. Paul, 1875; Guttenberg, Iowa, 1876-7; Fountain City, Wisconsin, 1880-1; LaCrosse, Wisconsin, 1882; Elkader, Iowa, 1880-94.

In the following list the synonomy used is that of Gray's Manual, 7th edition.

FILICES

Adiantum pedatum L. St. Paul, Minnesota.
Camptosorus rhizophyllus Link. Elkader, and Guttenberg, Iowa.
Onoclea sensibilis L. St. Paul.
Botrichium virginianum (L) Sw. St. Paul.

PINACEAE

Juniperus virginiana L. St. Cloud, Minnesota.

ALISMACEAE

Sagittaria arifolia Nutt. Elkader.

GRAMINEAE

Echinochloa crus-galli (L) Beauv. St. Cloud.
Sorghastrum nutans (L) Nash. St. Cloud.
Bouteloua curtipendula (Michx) Torr. St. Cloud.
Eragrostis megastachya (Koeler) Link. St. Cloud.
Elymus canadensis L. St. Cloud.

CYPERACEAE

Cyperus ferax Richards. St. Cloud; Guttenberg, Iowa.
C. rivularis Kunth. Fountain City, Wisconsin.
Scirpus atrocinctus Fernald. St. Paul.
S. atrovirens Vahl. St. Paul.

Carex comosa Boett. St. Paul.
C. stipata Muhl. St. Paul.

ARACEAE

Arisaema triphyllum (L) Schott. St. Cloud; Guttenberg.
Symplocarpus foetidus (L) Nutt. Fountain City.

COMMELINACEAE

Tradescantia reflexa Raf. La Crosse.
T. bracteata Small. St. Paul.

LILIACEAE

Zygadenus chloranthus Richards. St. Cloud; La Crosse.
Uvularia grandifolia Smith. Guttenberg.
Oakesia sessilifolia (L) Wats. St. Cloud.
Allium stellatum Ker. St. Cloud.
Lilium philadelphicum L. var *andinum* (Mill) Ker. St. Cloud; La Crosse.
L. superbum L. St. Cloud; La Crosse.
Erythronium albidum Nutt. Elkader; Guttenberg.
Smilacina stellata (L) Desf. St. Cloud; St. Paul.
S. racemosa (L) Desf. St. Paul.
Maianthemum canadense Desf. St. Paul.
Streptopus roseus Michx. Two Rivers, Minnesota.
Trillium declinatum (Gray) Gleason. St. Cloud; Guttenberg.
T. nivale Riddell. Elkader.
Smilax ecirrhata (Eng.) Wats. St. Cloud.

AMARYLLIDACEAE

Hypoxis erecta L. St. Cloud; St. Paul.

IRIDACEAE

Iris versicolor L. St. Paul; Guttenberg.
Belamcauda chinensis (L) DC. St. Cloud.
Sisyrinchinum angustifolium Mill. St. Paul; St. Cloud.

ORCHIDACEAE

Cypripedium candidum Muhl. St. Cloud.
C. parviflorum Salisb. St. Paul.
C. hirsutum Mill. St. Cloud; St. Paul.
Calopogon pulchellus (Sw) R. Br. St. Cloud; St. Paul.
Habenaria Hookeri Torr. St. Paul; Elkader.

SALICACEAE

Salix candida Flugge. St. Cloud.

BETULACEAE

Ostrya virginiana (Mill) K. Koch. St. Cloud.

FAGACEAE

Quercus macrocarpa Michx. St. Cloud.
Q. rubra L. St. Paul.
Q. velutina Lam. St. Paul.

URTICACEAE

Pilea pumila (L) Gray. La Crosse.

SANTALACEAE

Comandra umbellata Torr. St. Paul.

ARISTOLOCHIACEAE

Asarum canadense, L. St. Cloud.
A. canadense var. *acuminatum* Ashe. Guttenberg.

POLYGONACEAE

Polygonum lapathifolium L. St. Cloud.

NYCTAGINACEAE

Oxybaphus hirsutus (Pursh) Sweet. St. Cloud.

CARYOPHYLLACEAE

Arenaria lateriflora L. St. Paul.

PORTULACCACEAE

Claytonia virginica L. Guttenberg.

RANUNCULACEAE

Ranunculus septentrionalis Poir. St. Cloud.
R. abortivus L. St. Cloud.
R. rhomboideus Goldie. St. Cloud; La Crosse.
R. pennsylvanicus L. St. Cloud.
Thalictrum dasycarpum Fisch. & Lall. St. Cloud; St. Paul.
T. dioicum L. St. Cloud.
Anemonella thalictroides (L) Spach. Guttenberg.
Hepatica triloba Chaix. Guttenberg.
Anemone patens var. *Wolfgangiana* (Bess) Koch. Fountain City.
A. nemorosa L. St. Paul.
A. canadensis L. St. Paul.
A. virginiana L. St. Cloud.
Aquilegia canadensis L. St. Cloud.
Delphinium Penardi Huth. St. Paul.
Actaea rubra (Ait) Willd. Guttenberg.

BERBERIDACEAE

Podophyllum peltatum L. Guttenberg.

PAPAVERACEAE

Sanguinaria canadensis L. Guttenberg.

FUMARIACEAE

Dicentra cucullaria L. Guttenberg; Wahpeton, Iowa.
D. canadensis (Goldie) Walp. Elkader.
Corydalis micrantha Eng. St. Cloud.

CRUCIFEREAE

Dentaria laciniata Muhl. Elkader.
Arabis lyrata L. Guttenberg.
A. Drummondii Gray. St. Paul.
A. laevigata (Muhl.) Poir. St. Cloud.

CAPPARIDACEAE

Polanisia trachysperma T. & G. St. Paul.
Heuchera hispida Pursh. St. Cloud.
Mitella diphylla L. St. Paul; Guttenberg.
Parnassia caroliniana Michx. Fountain City.
Ribes gracile, Michx. St. Cloud.
R. floridum L'Her. St. Cloud.

ROSACEAE

Physocarpus opulifolius (L) Maxim. St. Cloud.
Spiraea salicifolia L. St. Cloud.
Amelanchier spicata Lam. St. Cloud.
Crataegus punctata Hook. St. Cloud.
Potentilla canadensis L. St. Paul.
P. monspeliensis L. St. Cloud.
P. argentea Pursh. St. Paul.

P. anserina L. St. Cloud.
P. palustris (L) Scop. St. Paul.
Geum strictum Ait. St. Cloud.
G. triflorum Pursh. St. Cloud.
Rubus alleghaniensis Porter. St. Paul.
Prunus virginiana L. St. Cloud.

LEGUMINOSAE

Baptisia bracteata Ell. Elkader.
B. leucantha T. & G. Fountain City.
Lupinus perennis L. St. Cloud.
Psoralea argophylla Pursh. St. Paul.
Amorpha canescens Nutt. St. Paul.
A. microphylla Pursh. St. Cloud.
Petalostemon candidum Michx. St. Paul.
P. purpurascens (Vent.) Ryd. St. Paul; St. Cloud.
Tephrosia virginiana (L) Pers. Fountain City.
Astragalus canadensis L. St. Paul.
Desmodium canadense L. St. Cloud.
D. illinoense Gray. St. Cloud.
D. grandiflorum (Walt) DC. St. Cloud.
D. Dillenii Darl. St. Cloud.
Vicia americana Muhl. St. Cloud.
Lathyrus venosus Muhl. St. Paul; St. Cloud.
Amphicarpa monoica (L) Ell. St. Cloud.

LINACEAE

Linum sulcatum Riddell. St. Cloud.

OXALIDACEAE

Oxalis violacea L. St. Cloud.
O. corniculata L. St. Paul.

GERANIACEAE

Geranium maculatum L. St. Cloud.

RUTACEAE

Zanthoxylum americanum Mill. St. Cloud.

POLYGALACEAE

Polygala senega L. St. Cloud; St. Paul.
P. sanguinea L. St. Cloud; Fountain City.

EUPHORBIACEAE

Euphorbia corollata L. St. Paul; La Crosse.
E. glyptosperma Eng. St. Cloud.

ANACARDIACEAE

Rhus glabra L. St. Paul.

BALSAMINACEAE

Impatiens pallida Nutt. St. Cloud.

RHAMNACEAE

Ceanothus americanus L. St. Paul; Guttenberg; La Crosse.

HYPERICACEAE

Hypericum Ascyron L. St. Cloud; La Crosse.
H. maculatum Walt. La Crosse.

VIOLACEAE

Viola papilionacea Pursh. St. Cloud.
V. pedatifida G. Don. St. Cloud.

LYTHRACEAE

Lythrum alatum L. St. Cloud.

ONAGRACEAE

Oenothera biennis L. St. Cloud.
Epilobium angustifolium L. St. Cloud.
Circaea lutetiana L. St. Cloud.

ARALIACEAE

Aralia nudicaulis L. St. Cloud; St. Paul.

UMBELLIFERAE

Sanicula gregaria Bicknell. St. Paul.
Osmorrhiza Claytoni (Michx) Clarke. St. Paul.

CORNACEAE

Cornus paniculata L'Her. St. Cloud.
C. circinata L'Her. St. Cloud.
C. alternifolia L. fil. St. Cloud.

ERICACEAE

Vaccinium pennsylvanicum L. St. Cloud.
Gaylussacia baccata (Wang) K. Koch. St. Paul.
Pyrola rotundifolia L. St. Paul.
P. elliptica Nutt. St. Paul.
Andromeda polifolia L. St. Cloud.

PRIMULACEAE

Lysimachia terrestris (L) B.S.P. Fountain City.
L. quadrifolia L. La Crosse.
Steironema ciliata Raf. St. Paul; La Crosse.
S. lanceolatum (Walt) Gray. Guttenberg.
Dodecatheon Meadia L. Guttenberg.

GENTIANACEAE

Gentiana Andrewsii Griseb. St. Cloud; La Crosse.
G. flavida Gray. St. Cloud.
G. crinita Froel. St. Cloud; Fountain City.
G. puberula Michx. St. Cloud.
G. quinquefolia L. Fountain City.

APOCYNACEAE

Apocynum androsaemifolium L. St. Paul.
A. cannabinum L. Guttenberg.

ASCLEPIADACEAE

Asclepias tuberosa L. St. Paul.
A. incarnata L. St. Paul.
A. ovalifolia Dec. St. Paul.
Acerates viridiflora Dec. St. Paul.
A. lanuginosa (L) Dec. St. Paul.

POLEMONIACEAE

Phlox pilosa L. St. Cloud; St. Paul.
P. divaricata L. Guttenberg.
Polemonium reptans L. Guttenberg.

HYDROPHYLLACEAE

Hydrophyllum virginicum L. St. Cloud.
Ellisia Nyctelea L. Guttenberg.

BORAGINACEAE

Mertensia virginiana (L) Link. Guttenberg.
Lithospermum canadense Nutt. St. Paul; St. Cloud.
L. Gmelini (Michx) Hitch. St. Paul; St. Cloud.
L. angustifolium Michx. Fountain City.
Onosmodium occidentale Mackenzie. La Crosse.

VERBENACEAE

Verbena bracteosa Michx. St. Cloud.

LABIATAE

Teucrium canadense L. St. Paul.
Scutellaria parvula Michx. St. Cloud.
S. lateriflora L. St. Cloud; Guttenberg.
Agastache foeniculum (Pursh) Kuntze. St. Cloud.
Nepeta cataria L. St. Paul.
Dracocephalum parviflorum Nutt. St. Cloud.
Prunella vulgaris L. St. Cloud; La Crosse.
Physostegia virginiana L. St. Cloud; Guttenberg.
Leonurus cardiaca L. St. Paul.
Monarda fistulosa L. St. Paul.
M. punctata L. Fountain City.
Hedeoma hispida L. La Crosse.
Pycnanthemum virginianum (L) Dur. & Jack. St. Cloud.
Lycopus americanus Muhl. St. Cloud.

SOLANACEAE

Physalis lanceolata Michx. St. Paul.
Solanum nigrum L. St. Cloud.

SCROPHULARIACEAE

Linaria vulgaris L. St. Cloud.
Pentstemon pubescens Sol. St. Cloud.
P. grandiflorus Nutt. St. Cloud; St. Paul.
Chelone glabra L. Fountain City.
Mimulus Jamesii T. & G. St. Paul.
M. ringens L. St. Paul.
Veronica virginica L. St. Cloud; La Crosse.
Gerardia tenuifolia Vahl. Elkader; St. Cloud.
G. pedicularia L. Fountain City.
Castilleia sessiliflora Pursh. St. Cloud.
C. coccinea (L) Spreng. Fountain City; St. Cloud; St. Paul.
Pedicularis canadensis L. St. Cloud.
P. lanceolata Michx.

RUBIACEAE

Galium boreale L. St. Paul.
G. trifidium Michx. St. Paul.
Houstonia purpurea L. St. Cloud.

CAPRIFOLIACEAE

Diervilla trifida (L) Moench. St. Paul.
Lonicera dioica L. St. Paul; St. Cloud.
Symphoricarpus occidentalis Hook. St. Paul.
Viburnum pubescens (Ait.) Pursh. St. Paul.
Viburnum lentago L. St. Cloud.
V. opulus var. *americanum* (Mill) Ait. St. Cloud.
Sambucus canadensis L. St. Cloud.

VALERIANACEAE

Valeriana edulis Nutt. Fountain City.

CUCURBITACEAE

Echinocystis lobata (Michx.) T. & G. St. Cloud.

CAMPANULACEAE

Campanula americana L. St. Paul; St. Cloud.
C. rotundifolia L. St. Paul.

LOBELIACEAE

Lobelia spicata Lam. St. Paul; La Crosse.
L. cardinalis L. Guttenberg.
L. syphilitica L. Guttenberg.

COMPOSITAE

Eupatorium urticaefolium Reichard. St. Cloud.
E. perfoliatum L. St. Cloud.
E. purpureum L. St. Cloud; Fountain City.
Liatris scariosa Willd. St. Cloud.
L. pychnostachya Michx. La Crosse.
Solidago canadensis L. St. Cloud.
S. speciosa var. *angustata* T. & G. St. Cloud.
S. rigida L. La Crosse; St. Cloud.
S. graminifolia (L) Salisb. St. Cloud.
Aster novae-angliae L. St. Cloud.
A. sericeus Vent. St. Paul; Fountain City.
A. patens L. St. Cloud; Fountain City.
A. Drummondii Lindl. St. Cloud.
A. ericoides L. Fountain City.
A. multiflorus Ait. Fountain City.
A. umbellatus Mill. La Crosse.
A. ptarmicoides T. & G. St. Cloud.
Erigeron philadelphicum L. St. Paul.
E. ramosus (Walt.) B.S.P. St. Paul.
E. canadensis L. St. Cloud.
Antennaria plantaginifolia (L) Richards. St. Paul.
Gnaphalium polycephalum Michx. La Crosse.
Heliopsis scabra Dunal. St. Paul.
Rudbeckia hirta L. St. Paul.
Helianthus strumosus L. St. Cloud.
H. strumosus var. *mollis* T. & G. St. Cloud.
Coreopsis palmata Nutt. St. Paul.
Bidens cernua L. St. Cloud.
B. frondosa L. St. Cloud.
Helenium autumnale L. St. Cloud.
Tanacetum vulgare L. St. Cloud.
Artemisia frigida Willd. St. Cloud.
Cacalia reniformis Muhl. Elkader.
Senecio balsamitae Muhl. St. Paul.
Arctium minus Bernh. St. Cloud.
Cirsium iowense (Pammel) Fernald (*Cnicus iowensis Crattyi* Pammel) St. Cloud.
C. discolor (Muhl.) Spreng. Fountain City.
Krigia amplexicaulis Nutt. St. Cloud.
Prenanthes alba L. St. Cloud.
P. aspera Michx. St. Cloud.
P. racemosa Michx. La Crosse.
Hieracium canadense Michx. St. Cloud.

DEPARTMENT OF BOTANY
IOWA STATE COLLEGE

TWO ADDITIONS TO OUR LIST OF CRUCIFERAE

R. I. CRATTY

Two species of the mustard family not heretofore recorded from Iowa, so far as is known to the writer, have recently come to his notice, namely; *Brassica juncea* (L) Cosson, or Indian mustard, and *Lepidium perfoliatum* L. a noteworthy species of pepper-grass.

The credit for detecting the former is due Miss Charlotte M. King, Seed Analyst of the Iowa State College, who found the seed in a sample of timothy seed received from Pocahontas county for testing as to purity and germination. From these seeds the writer last season grew some plants in his garden for the purpose of study. More recently Miss King has detected it as an impurity in *Melilotus indica* seed from Delaware county, and in alfalfa seed from Orange City, and occasionally in clover and rape seed.

This plant, a native of Asia, apparently has been quite common in the northern part of the state for the past twenty-five years, but has been confused with the equally noxious *Brassica arvensis* (L) Kuntze, both of which were introduced with flax seed, and have since become very widely distributed over the state. Wherever mustards occur in grain fields, one or both of these is likely to be found.

The two plants are easily distinguished when once they are understood, especially when they are in fruit. *B. arvensis* has the mature fruit pods on short, stalky pedicels, the leaves are rough or bristly, and the seeds are smooth. *B. juncea* has the mature pods or slender pedicels which are about twice the length of those of *B. arvensis,* the leaves and stems are smooth throughout and the ripe seeds are conspicuously covered with minute pits. *Brassica nigra* (L) Koch, the common black mustard, to which *B. juncea* is more closely related than to *B. arvensis,* is our most common mustard on roadsides and in waste places. It is a much taller species with long slender fruiting branches with appressed pedicels and small dark seeds. In the flowering state *B. juncea* and *B. nigra* look much alike, the leaves being very

Fig. 32. Left hand specimen: *Brassica arvensis* (L.) Kuntze. Right hand specimen: *Brassica juncea* (L.) Cisson. Photo by Mr. Richardson.

similar, but the latter species has some bristles on the lower portion of the stem and along the midrib of the lower leaves.

The following specimens of *B. juncea* are in the Iowa State College herbarium; Kossuth County, 1897; Emmet county, 1897, 1898, 1901 and 1902; Ames, 1907, 1908 and 1913; Frazer, 1911; Kelley, 1911; Marathon, 1908; Spirit Lake, 1920, and Alden, without date.

The second plant, *Lepidium perfoliatum* L., is probably a very

Fig. 33. *Lepidium perfoliatum* L.

recent emigrant from Europe, and so far as the writer has been able to learn, is not recorded in any of our manuals, except in Rydberg's Flora of the Rocky Mountains. It is a native of southern Europe and the Orient, the two sheets of the species in the writer's herbarium being from Austria. This plant was first collected in Iowa by Dr. H. S. Conard of Grinnell College who found it growing on Hamlin Street in Grinnell in June, 1918, and

Fig. 34. *Lepidium perfoliatum*; left hand specimen from Grinnell; right hand specimen from Kelley. Photo by Mr. Richardson.

who has kindly sent me a specimen. However, Dr. Ada Hayden of the Iowa State College, while collecting weed specimens with her class in September, 1920, found it growing on the Inter-urban right-of-way at Kelley, Iowa. The plants at that time were very mature and bore only the entire leaves. Some of the seeds were at once sown in the writer's garden, and a number germinated and early the following spring showed pretty rosettes of pinnately dissected leaves. This diversity in foliage is very remarkable, and Engler and Prantl make particular mention of it in their *Naturlichen Pflanzenfamilien.* The finely dissected leaves continue to appear till the plant is several inches high, when the entire perfoliate ones appear on the upper portion of the stem and

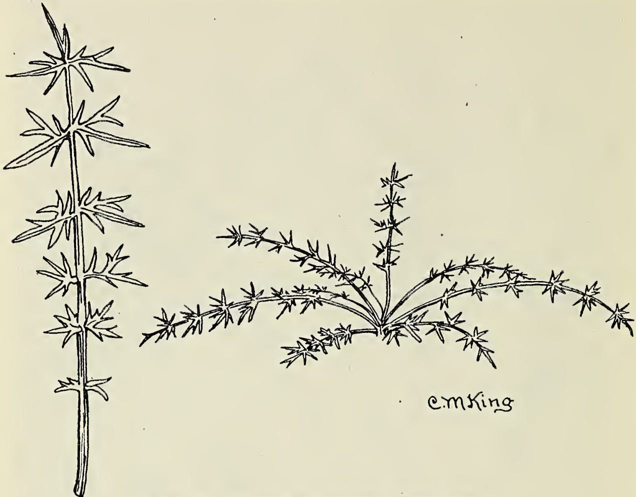

Fig. 35. *Lepidium perfoliatum,* juvenile form.

on the branches. Late in the season the dissected leaves frequently disappear entirely, thus giving the plant a strikingly different appearance from its early state.

Dr. B. L. Robinson, Curator of the Gray Herbarium, to whom an Iowa specimen was sent, says that it has been reported on several occasions from other parts of the country. He cites references to this species as follows: Rhodora XIX, 225 (1917), where it was reported from an old cultivated field at Barkhamsted county, Massachusetts (*A. E. Blewitt*). Rhodora XVIII, 219 (1916), where reported from ballast ground, Chelsea Bridge, Charlestown (*C. E. Perkins*). Torreya XIII, 258 (1913), where it is reported by *A. O. Garrett* as becoming abundant in Salt Lake county, Utah.

Doctor Robinson reports specimens in the Gray Herbarium from the following localities: Kent, Portage county, Ohio, where it was collected "naturalized" in lawns by *L. S. Hopkins;* from Courtney, Missouri, "along railroads" *B. F. Bush;* vicinity of Salt Lake, Utah, from three collectors; stony shores, Pyramid Lake, Washoe county, Nevada, *P. B. Kennedy;* Grand Canyon, Arizona, *V. Rattan;* Orange, California, *Mrs. N. F. Bradshaw;* and at a half-dozen different stations in Oregon where collected first by *Suksdorf* and later by *J. C. Nelson.* The above would indicate that the plant is becoming widely distributed in the United States.

Department of Botany
Iowa State College

THE TEACHING OF PLANT PATHOLOGY

L. H. PAMMEL

Mr. Chairman:

I am sorry that Doctor Melhus because of sickness is unable to be with you to present the subject of plant pathology from the standpoint of a special teacher. I have not had time to get a paper ready for you and what I shall say will be entirely informal and not necessarily a connected discourse.

In recent years I have given little attention to the subject of plant pathology at Ames, feeling it is in good hands. During my early career at Ames I had some experience in giving some training to students in this subject.

Let me say first of all that no one should take up the subject of plant pathology unless there is first of all a good fundamental training in general botany and related sciences. Opinions may differ as to how much of this fundamental work should be given. I am inclined to think there should be at least one year's work of five hours per week. This will enable the student to take up the general morphology of flowering plants, histology and a brief study of lower forms like the algae and fungi. I wish there might be added to this general one year course in botany a course dealing with the taxonomy of the flowering plants. The student of plant pathology should know the common seed plants so that these can be identified for the purpose of having a knowledge of the parasitic fungi of our wild plants. It requires a good keen sense of wild plants to be able to recognize plants in their juvenile stage and many parasitic fungi occur on the young plants. Can courses in plant pathology be given in a pedagogical way? I think they can. The beginner should learn how to use his material in the best way. First of all it is important to learn something about the general character of fungi. A hand lens is indispensable for the work. Let us say the student has the downy mildew of the grape (*Plasmopara viticola*). The macroscopic characters are so evident that the student cannot be led astray. The peculiar yellow spot on the upper surface of the leaf and the frosty mildew on the lower surface are characteristic. With a little practice the student soon will be able to recognize the downy mildews. If now the student is familiar with the host plant he will have no trouble in placing the fungus in the genus and species. Of course this cursory examination should be followed by placing some of the material under the compound microscope. The student can then make a further study, if he has fresh material, of the germination of the conidia and if the proper material is at hand inoculation experiments can be made in the greenhouse producing the disease on the wild uncultivated grape. It goes without saying that every well regulated laboratory in plant pathology should have a greenhouse, though this is not absolutely necessary. Seedlings of radish and mustard can be grown in pots, covered with bell jars to get the proper moisture relations and then one can produce the downy mildew of mustards on these plants, or the white rust. Let us take another well known illustration — the common wheat rust. What student has not seen the yellow spot on the barberry leaf with the little black specks, the spermogonia, and on the lower surface the cuplike bodies? With a good hand lens the fringed cup and spores may be seen. One who knows can tell the *uredo sori* of *Puccinia coronata* from *P. graminis.* How easy it is also to recognize by macroscopic characters the difference between *Gymnosporangium macropus* and *G. globosum,* a difference between the perennial and annual gall of the two species.

No one could make a mistake in the identification of the common bunt of wheat (*Tilltia foetens*) and loose smut of wheat (*Ustilago Tritici*). One could hardly make a mistake between loose smut of oats (*Ustilago avenae*) and the covered loose smut (*Ustilago laevis*). In a study of the macroscopic characters of such diseases as Illinois canker one could hardly make a mistake. Nor could we make a mistake in the two forms of plum pockets commonly found on the wild plum, the *Exoascus prunii* and *E. communis,* the former on the plum and the latter on branches of the Miner plum. There is nothing else exactly like the black knot of the plum and one should be able to place it without much trouble.

In modern courses in plant pathology growing pure cultures form a part of the regular work. Pure cultures of the organism can be used to inoculate plants and the lesions produced may be studied. Of course inoculations with diseased plant material can be made with such diseases as sorghum blight, apple blight and rust.

I hope you will pardon this somewhat disconnected discussion of the topic before us.

Department of Botany
Iowa State College

TREES OF THE PROPOSED MISSISSIPPI VALLEY NATIONAL PARK

L. H. PAMMEL

I am including in this list the trees found within a radius of 30 to 40 miles, which, therefore, includes some trees on the Wisconsin side of Mississippi river, especially a few species found near Muscoda and the mouth of Kickapoo river. I have also listed a few evergreen shrubs.

White pine (*Pinus strobus*), L., Waterville, Yellow, Kickapoo and Wisconsin rivers.

Jack pine (*Pinus Banksiana* Lamb), only on the Wisconsin side of the Mississippi, a few trees below the mouth of Kickapoo river, abundant at Muscoda.

Balsam fir (*Abies balsamea* (L) Mill.), on Yellow river, Allamakee county, and Oneota river, Winneshiek county.

Hemlock (*Tsuga canadensis* (L) Carr), on Kickapoo river near Rockton.

Red Cedar (*Juniperus virginiana* L.), bluffs, common.

Common juniper (*Juniperus communis* L.), with us only a shrub, however, a tree in some sections of the United States; common, limestone bluffs.

Yew (*Taxus canadensis* Marsh), only a shrub. This is the only conifer in this immediate vicinity.

Black willow (*Salix nigra* Marsh), banks of streams, common.

Peach leaved willow (*Salix amygdaloides* Anders), common, banks of streams.

White willow (*Salix alba* L.), introduced.

Sandbar willow (*Salix longifolia* Muhl.), common on sandbars and streams.

Pussy Willow (*Salix cordata* Muhl.), springy places, streams.

Pussy willow (*Salix discolor* Muhl.), springy places.

Beaked willow (*Salix rostrata* Richard), in bogs.

White or silver poplar (*Populus alba* L.), introduced.

Quaking aspen (*Populus tremuloides* Michx), uplands, common.

Large toothed aspen (*Populus grandidentata* Michx), upland woods, common.

Balm of Gilead (*Populus candicans* Ait.), introduced.

Cottonwood (*Populus deltoides* Marsh), low lands, common.

Butternut (*Juglans cinerea* L.), common, slopes of hills.

Black walnut (*Juglans nigra* L), common, alluvial bottoms, and lower slope of hills.

Shellbark hickory (*Carya ovata* (Mill) K. Koch), common, upland woods.

Pignut hickory (*Carya cordiformis* (Wang) K. Koch), common.

Hop hornbeam (*Ostrya Virginiana* (Mill) Koch), common.

Ironwood or blue beech (*Carpinus caroliniana* Walt), shady slopes.

Cherry, yellow or gray birch (*Betula lutea* Michx), sandy, moist ravines below Pikes Peak, Yellow river region.

Black or river birch (*Betula nigra* L.), Mississippi river bottoms.

Paper birch (*Betula papyrifera* Marsh), common, limestone bluffs.

White oak (*Quercus alba* L), common, upland woods.

Bur oak (*Quercus macrocarpa* Michx), common.

Swamp white oak (*Quercus bicolor* Willd), common, Mississippi river bottoms.

Chestnut oak (*Quercus Muhlenbergii* Engelm), exposed slopes of hills.

Red oak (*Quercus rubra* L.), common.

Yellow oak (*Quercus ellipsoidalis* E. J. Hill), sandy soil.

Quercitron oak (*Quercus velutina* Lam), sandy soil and sandy washes.

Slippery elm (*Ulmus fulva* Michx), common in upland woods.

American or white elm (*Ulmus americana* L.), along streams and in alluvial bottoms, common.

Hackberry (*Celtis occidentalis* L.), common along streams and bottoms.

Red mulberry (*Morus rubra* L.), not infrequent, upland woods, along Mississippi river.

Papaw (*Asimina triloba* Dunal), Mr. Kenyon, formerly in nursery business at McGregor, reported the species at McGregor, supposed to have been planted there by the Indians.

Sycamore (*Platanus occidentalis* L.), a few trees south of McGregor, mouth of Turkey river, rare.

Wild crab (*Pyrus ioensis* (Wood) Bailey), common in woods forming thickets.

Mountain ash (*Pyrus americana* (Marsh) D. C.), along Yellow river, rare.

European mountain ash (*Pyrus Aucuparia* L.), occasionally escaped from cultivation.

Service berry (*Amelanchier canadensis* (L.) Medic), common, rocky woods and hillsides.

Red haw (*Crataegus mollis* (T. & G) Scheele).

Red haw (*Crataegus punctata* Jacq.)

Red haw (*Crataegus coccinea* Mill).

Wild plum (*Prunus americana* Marsh), common, forming thickets.

Black or rum cherry (*Prunus serotina* Ehrh.), common.

Red or pin cherry (*Prunus pennsylvanica* L. f.), not infrequent.

Kentucky coffee tree (*Gymnocladus dioica* (L.) Koch), banks of Mississippi river.

Honey locust (*Gleditsia triacanthos* L.), banks of Mississippi river.

Black locust (*Robinia Pseudo-Acacia* L.), escaped from cultivation.

White or silver maple (*Acer saccharinum* L.), alluvial bottoms, common.

Sugar maple (*Acer saccharum* Marsh), the common hard maple.

Black maple (*Acer nigrum* (Michx) Britton), along Yellow river, less common than the sugar maple.

Box elder (*Acer negundo* L.), common.

Basswood (*Tilia americana* L.), common, upland woods.

Black ash (*Fraxinus nigra* Marsh), low swampy grounds, common.

White ash (*Fraxinus americana* L.), tops of hills and sides, generally in exposed places, small tree, nearly its northern limit.

Green ash (*Fraxinus lanceolata* (Borkh.) Sarg.), common, alluvial bottoms and streams.

Red ash (*Fraxinus Pennsylvanica* (Marsh)), not certain of its occurrence, branches and petioles velvety pubescent.

SHRUBS OF THE McGREGOR DISTRICT

L. H. PAMMEL

The writer has included shrubs found as far north as La Crosse, Wisconsin, where several tamarack swamps occur with their peculiar shrubs; also shrubs of Allamakee and Winneshiek counties where Doctor Shimek has found a number of most interesting shrubs.

Yew (*Taxus canadensis*), not uncommon, Yellow river region, evergreen.

Common juniper (*Juniperus communis* L.), limestone rocks, evergreen.

Green Brier (*Smilax rotundifolia*), spiny, green stemmed climbing shrub.

Moonseed (*Menispermum canadense* L.), common climbing shrub with black fruit.

Common barberry (*Berberis vulgaris* L.), shrub with three spines, naturalized.

Hudsonia (*Hudsonia tomentosa* Nutt.), heathlike shrub, sand dunes, Muscoda, Wisconsin river.

St. John's wort (*Hypericum prolificum* L.).

St. John's wort (*Hypericum Kalmianum* L.).

Mountain holly (*Nemopanthes fascicularis* Raf.), damp woods, near La Crosse, rare.

Bittersweet (*Celastrus scandens* L.), common in woods, climbing, pod orange color, seeds with scarlet membrane.

Wahoo (*Evonymus atropurpureus* Jacq.), erect shrub, seeds covered with red membrane.

Buckthorn (*Rhamnus alnifolia* L'Her), cold woods with balsam fir, Yellow river.

Common buckthorn (*Rhamnus cathartica* L.), a naturalized thorny branched shrub, rare.

Buckthorn (*Rhamus lanceolata* Pursh), at Dubuque and southern Clayton county, shrub not thorny, berry blackish.

New Jersey tea (*Ceanothus americanus* L.), low, white flowering shrub, border of woods, common.

New Jersey tea (*Ceanothus ovatus* Desf.), sandy soil.

Wild grape (*Vitis vulpina* L.), common.

Summer grape (*Vitis bicolor* LeConte), upland woods, McGregor district.

Virginia creeper (*Psedera quinquefolia* (L.) Greene), common in wood, forked tendrils with adhesive disks.

Virginia creeper (*Psedera vitacea* (Knerr) Greene), with disk tendrils.

Mountain maple (*Acer spicatum* Lam.), common in woods along the river.

Staghorn sumach (*Rhus typhina* L.), common, banks of streams, branches densely hairy, fruit red, hairy.

Common sumach (*Rhus glabra* L.), branches smooth, fruit smooth, red.

Poison ivy (*Rhus Toxicodendron* L.), common, climbing or erect shrub with three leaflets.

Poison oak (*Rhus Vernix* L.), in tamarack swamps near La Crosse.

Lead plant (*Amorpha canescens* Nutt.), common, low shrub with whitened hoary leaves.

False Indigo (*Amorpha fruticosa* Pursh), common, low grounds, greenish leaves.

Sand cherry (*Prunus pumila* L.), sand dunes and sandy prairies.

Meadow sweet (*Spiraea salicifolia* L.), in low grounds, white flowers.

Steeple bush (*Spiraea tomentosa* L.), on sand rocks, La Crosse region, rare.

Nine bark (*Physocarpus opulifolius* Maxim), common, hillsides.

Dwarf raspberry (*Rubus triflorus* Richard), bogs, La Crosse region, also Winneshiek county, Shimek.

Red raspberry (*Rubus strigosus* Michx), common in woods.

Black cap raspberry (*Rubus occidentale* L.), common in woods.

Blackberry (*Rubus nigrobaccus* Bailey), common.

Dew berry (*Rubus canadensis* L.), creeping on the ground.

Shrubby cinquefoil (*Potentilla fruticosa* L.), sandy rocks, La Crosse region, Winneshiek county, Shimek.

Three toothed cinquefoil (*Potentilla tridentata* Ait.), rare, sandy rocks, La Crosse region, Winneshiek county, Shimek.

Wild rose (*Rosa blanda* Ait.), woods.

Prairie rose (*Rosa pratincola* Greene).

Rose (*Rosa humilis* Marsh), Winneshiek county, Shimek.

Prickly rose (*Rosa Sayi* Schee), Winneshiek county, Shimek.

Woods' rose (*Rosa woodsii* Lindl), Winneshiek county, Shimek.

Black choke berry (*Pyrus arbutifolia* var *melanocarpa* Hook), Winneshiek county, Shimek.

Black currant (*Ribes floridum* L'Her), low woods.

Prickly gooseberry (*Ribes Cynosbati* L.), common in woods.

Smooth gooseberry (*Ribes gracile* Michx), common.

Witch hazel (*Hamamelis virginiana* L.), not uncommon.

Round leaved dogwood (*Cornus circinata* L'Her), common in upland woods.

Silky cornel (*Cornus sericea* L.).

Red osier (*Cornus stolonifera* Michx), common in La Crosse region.

Dogwood (*Cornus Amomum* Mill.), low grounds.

Alternate leaved dogwood (*Cornus alternifolia* L.f.), common.

Common elder (*Sambucus canadensis* L.), common.

Red berried elder (*Sambucus racemosa* L.), common in hills along the river.

Cranberry tree (*Viburnum Opulus* L.), common, Yellow river region.

Black haw (*Viburnum Lentago* L.), common.

Arrow-wood (*Viburnum dentatum* L.).

Twin flower (*Linnaea borealis* L.), in tamarack swamp, La Crosse region.

Snowberry (*Symphoricarpos occidentalis* Hook), rocky bluff.

Honeysuckle (*Lonicera Sullivantii* Gray), climbing shrub with yellow flowers.

Honeysuckle (*Lonicera glauca* Hill), in wood, reddish flowers, climbing.

Bush honeysuckle (*Diervilla trifida* Moench), in woods, yellow flowers.

Button bush (*Cephalanthus occidentalis* L.), low grounds.

Blue berry (*Vaccinium pennsylvanicum* Lam.), sandy woods, La Crosse region.

Cranberry (*Vaccinium macrocarpon* Ait.), tamarack swamp, La Crosse region.

Bearberry (*Arctostaphylos Uva-ursi* (L.) Spreng), sandy soil, Muscoda.

Smooth leaved Kalmia (*Kalmia polifolia*), found in peat bogs, tamarack swamps near La Crosse, Wis.

Wintergreen (*Gaultheria procumbens* L.), sandy soil, La Crosse region.

Matrimony vine (*Lycium vulgare* Dunal), introduced vine.

Moosewood (*Dirca palustris* L.), Allamakee county, yellow flowers.

Low birch (*Betula punctata* L.), peat bogs, La Crosse region.

Alder (*Alnus incana* Willd), swamps, Yellow river region.

Common hazel (*Corylus americana* Walt), common.

Beaked hazel (*Corylus rostrata* Ait.), Yellow river, Winneshiek county.

Shining willow (*Salix lucida* Muhl.), swamps, Winneshiek county, Shimek. La Crosse county.

Prairie willow (*Salix humilis* Marsh), opening border of woods.

Dwarf willow (*Salix tristis* Ait.), common prairies.

Hoary willow (*Salix candida* Willd), bogs, La Crosse region and northeast Clayton county.

Pussy willow (*Salix petiolaris* J. E. Smith), Winneshiek county, Shimek.

STUDIES IN THE GERMINATION OF SOME WOODY PLANTS

L. H. PAMMEL AND C. M. KING

The following brief study is a continuation of those previously reported to the academy. In the past these papers have been published in the Report of the Academy. One paper is in the hands of the Secretary. It is hoped to finally report on the germination of all of the native woody plants of Iowa, as well as the germination of a few exotics. In a study of the germination of these plants one is apt to notice striking characters, that cannot well be described. For instance, the young dogwood plants have an aspect peculiar to the family. For the first time, this year, a study has been made of the sugar maple (*Acer saccharum*). The glaucous character of the under surface of the leaf is just as pronounced in the young plants as in older leaves. Some seeds, like the maple, walnut and oaks, make a rapid progress in growth during germination. The eleagnus or oleaster on the other hand makes little progress at first.

Seeds of trees and shrubs were placed in the garden for stratification October 25, 1920, and transferred to soil in the greenhouse March 15, 1921.

Germinations were as follows: Beech (from White Lake, Michigan) (already sprouting) March 16, 1921.

Sugar maple (already sprouting) March 17, 1921.

Ptelea trifoliata (from Keokuk, Iowa) April 1, 1921.

Cornus Amomum (from Mason City, Iowa) April 1, 1921.

Cornus Amomum (from Avoca, Iowa) April 1, 1921.

Hemlock (from White Lake, Michigan) April 2, 1921.

Pecan (from Iowa) April 7, 1921.

Seeds of the following were not yet showing germination March 1, 1921: Mountain ash, speckled alder, paper birch, cherry birch, *Arbor vitae,* soft maple, *Rosa blanda, R. setigera, Cornus paniculata, Rhus glabra,* Yucca, dewberry, *Cornus circinata, Carpinus Caroliniana,* papaw, *Symphoricarpos occidentalis, Robinia Pseudo-Acacia, Sorbus scandia, Viburnum Opulus, Tilia americana,* sycamore and *Evonymus.* (The sycamore, *Evonymus* and

Tilia were not stratified, but were taken from the trees in March, 1921.)

Pinaceae

Tsuga canadensis (L.) Carr. Hemlock. See figure 36.

These seeds lay protected on the surface of garden soil from October 25, 1920, to March 25, 1921, when they were planted in the greenhouse. On April 2, 1921, first leaves made their appearance above ground.

Fig. 36. *Tsuga canadensis.* Hemlock. Hypocotyl, arched as it emerges. Young seedling bearing hull on tips of leaves. Seedling freed from hull. Drawn by C. M. King.

The first part to be seen is the arched hypocotyl; as soon as the leaves straighten they bring the hull of the seed with them, holding the tips of the leaves together. This hull clings to the seedling for some days before it is thrown off. When it is cast the cotyledons, three or four in number, emerge. They are of equal length (about half an inch), green with steel blue cast, slender, uniformly linear, faintly margined. The caulicle soon assumes an upright position and the cotyledons spread wide apart. The first series of true leaves, three to six in number, soon appear.

Juglandaceae

Carya illinoiensis (Wang.) K. Koch. See figure 37.

Placed in the garden for stratification October 28, 1920. Lifted after a mild winter, March 15, 1921, and transferred to the greenhouse. The shoot appeared above surface April 7, 1921; at end of two weeks had put out the first three leaves. Germination hypogaeous.

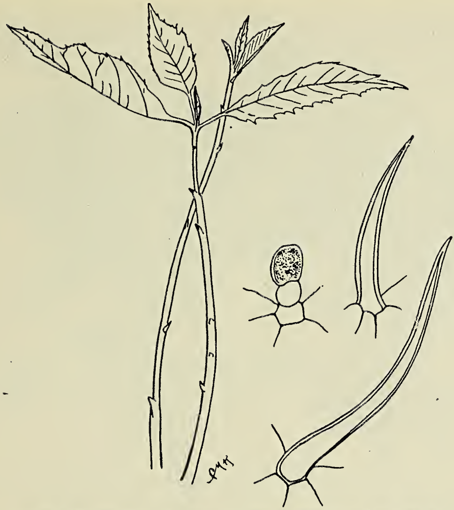

Fig. 37. *Carya illinoiensis.* Hickory. Young seedlings, two stages. Trichomes, and glandular hair, from stem. Drawn by C. M. King.

The stem reddish; bears numerous bracts, glandular pubescence. First leaf is simple; second is also simple; the third leaf shows beginning of separate leaflet at base; the fourth leaf bears the small leaflet; all leaves with sharp serrations and with fine scattered hairs along the veins on the under side. Upper surface of the leaves slightly pubescent.

Upon the plant, quite generally occur glandular hairs; these are short with the terminal cell enlarged, dark in color. The simple trichomes also numerous, are slender, pointed and colorless.

Fagaceae

Fagus grandifolia Ehrh. Beech. See figures 38, 39, 40.

Placed in soil, out of doors for stratifying October 25, 1920; transferred to greenhouse March 25, 1921. Many of the seeds were germinating when examined and all grew immediately upon being bedded in the greenhouse.

The three valves of the shell split apart, showing how the cotyledons are keeled and folded together in the seed. The ridge of the cotyledon folds into a corresponding groove of the other, the plumule lying between. The outer or lower side of the cotyledon is whitish becoming decidedly pink; the inner or upper one

Fig. 38. *Fagus grandifolia.* Beech. Cotyledons emerging from 3-valved shell. Young seedling, showing cotyledons and first pair of leaves. Drawn by C. M. King.

soon becomes light green. The radicle is long and slender, becoming brownish, the hypocotyl is thick, whitish in color. The feathery plumule is borne upon a slender stalk and is pubescent.

The first young leaves of the beech when unfolding are slightly

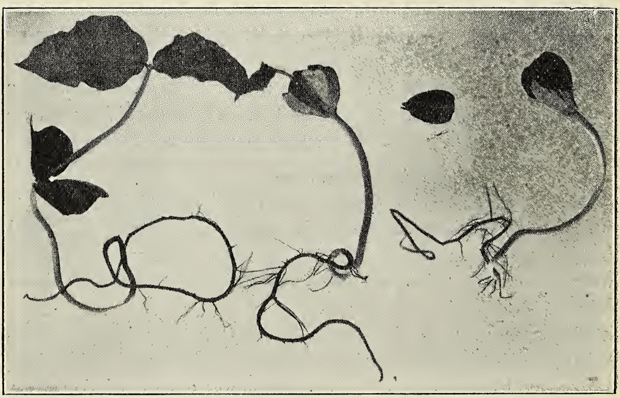

Fig. 39. Beech seedling at three early stages, showing shell borne on tip of folded cotyledons, and first pair of leaves. Photo by Mr. Richardson.

Fig. 40. Young seedlings of beech. Photo by Mr. Richardson.

rugose; they are ovate, pointed, with wavy margins and prominent veins. These leaves are sparsely hairy beneath, but decidedly hairy upon the upper surface, margins and petioles. The stem also is pubescent. The stipules are small, ovate, brownish and pubescent, falling early. Secondary roots soon appear upon the roots of the beech.

Saxifragaceae

Ribes floridum L'Her. Wild Black Currant. See figure 41.

Seeds from Backbone State Park; placed for outside stratifying October 25, 1920. Removed to greenhouse March 25, 1921. Germinated April 5, 1921. Growth of seedling rapid. Germination epigaeous, stem below cotyledons whitish; cotyledons oval, petiolate, smooth, somewhat fleshy. Leaves alternate; first leaf extipulate, smooth, petiole hairy. Second leaf similar. Leaves shallowly 5-lobed, dentate. Glandular hairs are numerous upon the

Fig. 41. *Ribes floridum.* Wild black currant. Seedling showing cotyledons and early leaves. Glandular hairs, on leaves and petioles. Drawn by C. M. King.

stem and petioles. These trichomes differ in length; they are slender, the cell at the top being enlarged.

Rutaceae

Ptelea trifoliata L. Hop tree. See figure 42.

Seeds stratified out of doors; planted in greenhouse March 25, 1921. First germination appeared April 1, 1921, the seedling growing rapidly. Germination hypogaeous. The hypocotyl whitish, slightly hairy. Cotyledons fleshy, broadly elliptical, about 1/3 of an inch in length, margin finely crenulate.

First leaf shining, crenate-margined, smooth above, simple. The following leaf compound, three crenately margined leaflets; third leaf the same.

Aceraceae

Acer saccharum Marsh. Sugar or Rock Maple. See figures 43, 44, 45, 46.

The seed was stratified out of doors in garden soil from October 25, 1920, till April 15, 1921. When lifted several seeds were already germinating and all grew readily when transferred to the greenhouse bench.

Fig. 42. *Ptelea trifoliata.* Hop tree. Young seedling, early stage, with seed coat still attached; cotyledons and plumule exhibited. Older seedling showing 3-parted leaves. Drawn by C. M. King.

Fig. 43. *Acer saccharum.* Hard maple. Samara. Young seedling showing cotyledons and first pair of leaves. Drawn by C. M. King.

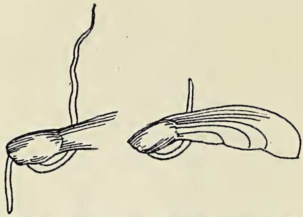

Fig. 44. Hard maple. Germinating seeds. Drawn by C. M. King.

Germination is epigaeous. The white radicle first pushes out of the seed coat at the basal end between the two samaras. The radicle is smooth, at first straight; the slightly curved caulicle is smooth, whitish, slender, slightly narrowed at the base; apex rounded. The first appearance above ground is the arch of the caulicle. The two strap shaped cotyledons are 3-veined. There

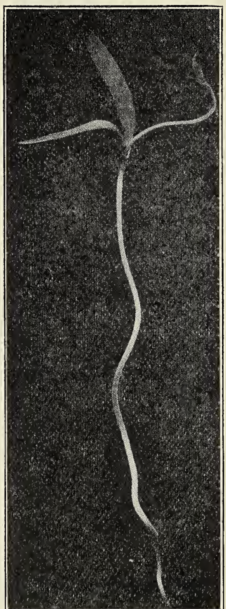

Fig. 45. Hard Maple. Seedling, showing cotyledons and plumule. Photo by Mr. Richardson.

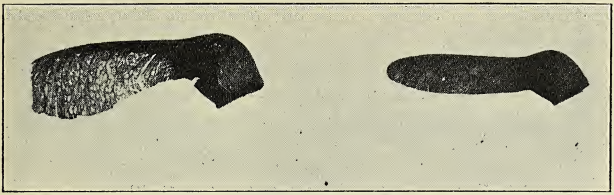

Fig. 46. Hard maple. Samara. parts separated. Photo by E. H. Richardson.

is a slight enlargement at the point where they are attached.

The plumule is feathery in appearance. The first pair of leaves is coarsely dentate and has the characteristic outline of the maple leaf. The stem between the cotyledons and the first pair of leaves is smooth. There are some hairs on the petioles, the leaf margins, and upon the veins on the lower side of the leaf. The lower side is lighter in color than the upper side.

Eleagnaceae

Eleagnus angustifolia L. Russian Olive. See figure 47.

April 5, 1921, young seedlings appeared freely under olive trees on the campus. The germinating seed lies in the soil close to the surface. The seedling cotyledon pushes off the hull and the white radicle descends, arching the hypocotyl.

The seedling develops very slowly. The two cotyledons, at first closely appressed, are about 1/3 of an inch in length, nearly oval, smooth, greenish, fleshy, distinctly auricled at the base. The

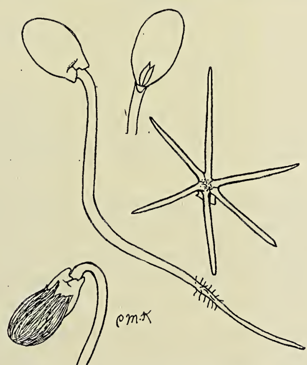

Fig. 47. *Eleagnus angustifolia.* Emerging cotyledons leaving seed coat. Young seedling cotyledons shown separated. Stellate trichome hair. Drawn by C. M. King.

surfaces show no veining. The tiny plumule is fleshy, pubescent with stellate hairs.

Cornaceae

Cornus Amomum Mill. Kinnikinnik. See figure 48.

These seeds were stratified out of doors through the winter;

Fig. 48. *Cornus Amomum.* Kinnikinnick. Young seedlings in two stages. Cotyledons and first pair of leaves shown. Drawn by C. M. King.

on March 15, 1921, they were planted in the greenhouse. On April 1, 1921, the first shoot appeared above ground.

Hypocotyl reddish; cotelydons foliaceous, oval to elliptical, 1/2 inch in length, green, smooth on both surfaces, pinnately veined. Plumule small, pubescent; first pair of leaves slightly pubescent on both surfaces, pinnately veined, lanceolate, entire. Petiole pubescent. Plumule slightly red; internode green. Aspect distinctly characteristic of the dogwood.

STUDIES OF THE PHYCOMYCETES OF IOWA

J. M. RAEDER

INTRODUCTION

Numerous papers and valuable collections of the Fungus Flora of the state have been contributed by earlier botanists. Due to the effort of such men as Halsted, Bessey, Arthur, Hitchcock, Holway and Pammel, a collection of over 200,000 specimens of the fungi of the state is assembled in the herbarium of Iowa State College and other prominent herbaria in America. These collections are listed and described in various papers which are scattered in numerous publications over a period of a half century.

It is obvious, then, that in order that such material be of value to students of mycology, it would seem desirable to collect it into some tangible form, by reexamining the specimens in the herbarium of Iowa State College, revising the nomenclature to conform to the more recent researches, and collecting and summarizing the literature bearing on the fungus flora of the state.

In the present paper the author has confined his efforts to one group, the Phycomycetes.

PHYCOMYCETES

Olpidiaceae

Olpidium saprolegniae Braun.
**Achlya* sp. (1). In terminal cells.

Synchytriaceae

Synchytrium anamalum Schroet.
Adox moschatellina (1). Holway; Decorah.
Synchytrium anemones (D. C.) Wor.
Anemone cylindrica. Ames; 1909.
Synchytrium decipiens Farl.
**Amphicarpa* sp. (1).
Amphicarpa monoica. Welch; Moingona, September 1900. Thomas; Ames, July, 1878. Anderson; Decatur Co., June, 1897. Melhus; Decorah, 1918.
Amphicarpa pitcheri. Anderson, Decatur County, July, 1905.
Apios tuberosa. Pammel; Ames, September, 1909.
Synchytrium Holwayi Farl.
**Monarda* sp. (12).
Saprolegnia ferax Gruith, Nees, Kutz.
*"On dead fish, cray-fish, etc., floating in water" (1).
Achlya prolifera Nees.
*"On decaying flies in water". (1).

* Not present in Herbarium.

Leptomitaceae

Leptomitus. lacteus Ag.
*"On decaying animal and vegetable matter in water". (4).

Pythiaceae

Pythium de Baryanum Hesse.
Attacks seedling plants and is called by gardeners "Damping Off." (4).

Albuginaceae

Cystopus candidus (Per) Lev.
"The white rust of crucifers". (1).
Brassica arvensis. Melhus; Clarion, June, 1907. Pammel; Ames, August, 1911.
Brassica nigra (3). Bessey; Ames, July, 1880.
Capsella bursa-pastoris (3) (6). Phode; Randolph. King; Ames, 1912. Anderson; Decatur County, May, 1904. Hitchcock; Ames. Pammel and Stewart. "No oöspores have been found, lives through the winter within the tissues of the seedling host plants." (2). "Confined to Cruciferae. lives over the winter within the tissue of seedling plants which spring up in autumn particularly in case of above host, which may account for the lack of formation of oöspores" (10).
**Lepidium apetalum* (6).
**Lepidium Virginicum* (6). Anderson; Decatur County, May, 1904. Pammel; Ames, September, 1890.
Radicula armoracia. Anderson; Decatur County, May, 1904. Pammel; Ames, September, 1890.
Radicula palustris. Bennett; Tripoli, July, 1912. Anderson; Decatur County, September, 1904. Fawcett; September, 1914. King; Ames, June, 1914.
**Radicula sessiliflora* (3).
Raphanus sativus (3). Pammel; Waukon, July, 1908. Pammel; Decorah, July, 1908. Stewart; Ames, September, 1893. McPherson; Council Bluffs, 1895. Pammel; Ames, September, 1900, September, 1901. Oöspores abundant in inflorescence (6).
Sisymbrium canescens.
Sisymbrium officinale (10). Anderson; Decatur County, 1898. Hitchcock; Ames.

Cystopus bliti (Bib) Dby.
**Acnida cannabina* (10).
Acnida tamariscina (3).
**Amaranthus* sp. (1).
**Amaranthus graecizans* (6). (10).
Amaranthus blitoides (10). Pammel; Ames, 1910. King; Ames, 1911.
Amaranthus hybridus (3) (10).
Amaranthus retroflexus (3), (10). Hitchcock; Ames. Pammel; Ames, 1910. King; Ames, 1910. Raymond; Ames, 1891. Bessey; Ames, September, 1882. Bessey; Ames, 1878. King; Ames, 1912. Pammel; Ames, September, 1902. Pammel; Ames, July, 1892.
Montelia tamariscina. "On leaves of common beet, no oöspores observed." (5).

Cystopus portulaceae (D. C.) Lev.
"On purslane" (1).
Portulaca oleraceae (3). Bessey; Ames, 1890. Raymond; Ames, 1891. Hitchcock; Ames. "Abundant on this host from middle of June to first of September. Oöspores abundant," (6). Halsted (10) reports it in 1886 to be more prevalent than ever on the above host in spite of drought. He accounts for this in that the host itself is a low growing succulent plant containing considerable moisture.

Cystopus ipomoeae-panduranae. (Lev). Farl.
Ipomoea batatas (4). Pammel; 1892. Pammel & Clarke; Hamburg. July, 1914.

Cystopus tragopogonis (Per). Schr.
**Ambrosia artemisiifolia.* "Abundant in June and early July." Halsted (10) reports the presence of the disease in 1888 on the above host, saying that this species of the fungus is the least common of the whole genus and was comparatively rare during the past two years.
**Ambrosia psilostachya* (3).
**Artemisia biennis.* Reported by Halsted on this host in 1885 (13).
**Parthenium integrifolium* (3).

Peronosporaceae

Phytophthora infestans (Mont.) D. By.
Solanum tuberosum (3). Stewart; Greenfield, 1903. Griffith; West Point, 1903. Halsted (2), (10) reporting this disease in 1886 says "it is the cause of potato rot. It has not been as prevalent as last year. The season has been dry and unfavorable to the development of the rot. Potatoes stored in cellars and pits where tubers rotted last winter are beginning to decay." Again in 1888 he reports that "there were no signs of the disease last season." "Past two seasons dry. Two years ago many complaints from all parts of the state. More than half of the potatoes in some sections rotted either before they were dug or in storage."

Phytophthora omnivora D. By.
Panax quinquefolium. Melhus.

Sclerospora graminicola (Sacc.) Schroet.
Setaria Italica (3). Pammel; Ames, August, 1889.
Setaria viridis (2), (3). Ames, August, 1889. Pammel; Ames, 1890, August, 1891. Combs; Ames, August, 1894. Pammel; Turin, September, 1894. Pammel; Jefferson, July, 1895. Pammel; Steamboat Rock, September, 1901. Pammel; Ames, 1911. Melhus; September, 1916. "Abunant during the latter part of May till middle of June, destroying large numbers of young plants of the above host. In whole patches it prevented the maturing of seeds." (4). "Not as common as in 1892. That year it took away whole patches of that miserable weed. After the fall rains in August the fungus increased somewhat." (8). "Common throughout the state in 1899." (9). Halsted (10) reported the presence of the disease in 1888. Less common that particular season.

Plasmopara viticola (B. and C.) B. and DT.
Vitis sp. Bakke; Ames, September, 1907.
Vitis labrusca (3). Bradford; Ames, 1911. Pammel; Boone, September, 1912.
Vitis vulpina (3). Bakke; Ames, September, 1907. "The frosty grape mildew has not been found on the cultivated grapes in this vicinity this season. In the spring the violent form of this fungus was discovered upon the leaves and canes of the common wildgrape (*Vitis vulpina*). Canes were dwarfed and covered with a white coat of conidial spores. Could not be propagated on the cultivated forms." (2). Halsted (10) in 1888 reports that two years previous to this date the canes of *Vitis vulpina* were dwarfed and covered with a thick coat of white, down to the earth's surface. None was found in 1887. Bessey (1) reports this disease in 1884 as follows. "Common from mid summer to autumn on leaves and young twigs." Destructive in 1902-03. (3). So abundant in 1892-93 as to threaten the cultivated grape (8).
Vitis bicolor. Pammel; McGregor, Iowa, June, 1920.
Psedera quinquefolia. Pammel; Ames, Cedar Rapids.

Plasmopara Halstedii Farl. B. and T.
"On many composites"(1).
**Ambrosia artemisiifolia* (3) (6).
**Ambrosia trifida* (6).
**Bidens cernua* (6).
**Bidens chrysanthemoides* (6).

Bidens connata (6). Pammel; Sheldahl, 1898.
Bidens frondosa (3) (6).
Bidens laevis (3).
Erigeron sp. According to Swingle (13) Holway reported this host at Decorah in July, 1884.
Eupatorium purpureum (3).
Helianthus annuus (6).
Helianthus doronicoides (3), (6).
Helianthus grosse-serratus (2), (3), (6).
Helianthus Maximiliani (3).
Helianthus tuberosus (6).
Rudbeckia laciniata (6). Melhus; Ames, June, 1916.
Rudbeckia triloba (6).
Silphium laciniatum (6).
Silphium perfoliatum (6).
Silphium sp. Ames, July, 1909.
Xanthium canadense (6).
On various members of the sunflower family. A new host reported in 1886. Destructive in 1902-03. "Not observed in 1894. Abundant on *Helianthus annuus, H. tuberosum* and other Composites a few years ago." (8). In 1888 Halsted (10) reported that the hosts were numerous, the leading ones being species of Helianthus, Silphium, Eupatorium, Bidens and others of the Compositae. *Bidens connata* var. *comosa* was added to the list of hosts this year.

Plasmopara pygmea (Ung.) Schroet.
"On wild anemones" (1).
Anemone canadensis. Ames, 1909. Pammel; Ames, 1910. Ames, 1911.
Anemone dichotoma (4).

Plasmopara Australis (Speg.) Swingle.
Echinocystis lobata (4).

Plasmopara geranii (Pk.) Berl and De Toni.
"On wild geranium" (1).
Geranium Carolinianum.
Geranium maculatum (4). Halsted (10) in 1888 reports it common on this host. Also states that Hitchcock found it this same year on *Geranium Carolinianum,* this making a new host for Iowa.
Peronoplasmopara cubensis (B. and C.) Cl.
Mormordica balsamina (3). "Mildew of squash and cucumber, usually under glass" (4).

Bremia lactucae Regel.
"On wild lettuce" (1).
"On lettuce" (4).
Lactuca ludoviciana (4). Hitchcock; Ames.
Lactuca canadensis. Pammel; Ames.
Lactuca sp. Melhus. Bessey; Ames, September, 1882. "Abundant in 1893" (6).
Lactuca leucophoea. "Occasionally appeared on lower leaves of this host" (10).
Prenanthes albus. Halsted (10) reports it on this host although he failed to find infection in 1888.

Peronospora obducens Schroet.
"Wild touch-me-nots infested" (1).
Impatiens pallida (3).
Impatiens biflora (10).

Peronospora parasitica (Pers.) Tul.
"On various crucifers" (1).
Brassica arvensis. Hitchcock; Ames.
Brassica campestris (6).
Brassica nigra (2), (4), (6).

Capsella bursa-pastoris (4), (6), (7). Hitchcock; Ames.
**Draba Caroliniana* (6), (12).
Lepidium apetalum (6), (7), (12). Ames, 1911. Pammel; Ames, May, 1918.
Lepidium Virginicum (2), (10). Hitchcock; Ames.
Lepidium sp. Stewart and Pammel. Anderson; Decatur County, June, 1904.
**Radicula palustris* (2), (4), (10).
**Raphanus sativus* (6).
Sisymbrium canescens (4).
Sisymbrium officinale (6).

"*Brassica nigra* and *Radicula palustris* were added to the list of hosts for Iowa in 1888. Another oösporic host, *Lepidium Virginicum,* also was added the same season. Oöspores were first found that year, June 28 (2). "Abundant on leaves and stems of *Lepidium apetalum* and *L. Virginicum,* killing the hosts." (6). "Abundant in April and May on leaves of *Lepidium apetalum,* completely infesting the whole plant, giving them a yellow appearance and stunted growth. It also occurred on *Capsella bursa-pastoris* but less abundantly" (7). "Is one of our most common species upon various cruciferous hosts. In ordinary seasons *Lepidium Virginicum* is much infested and has its branches strangely distorted. This year the pepper-grass has been quite free from attacks excepting the seedlings which for a few weeks were badly infested in the spring. This species lives over the winter in these seedlings and when spring comes the mildewed plants communicate the trouble to other plants by means of the multitude of conidial spores. The vigor of its attack upon the young pepper-grass makes this mildew one of the useful weed-destroyers. It deals in the same way with the shepherd's purse. Of all its hosts it has been most abundant upon *Radicula palustris.* In some species examined the conidiospores were not more than one-fourth the normal size. Other parts of the same patch, however, showed all gradations and it may be observed that a leaf parasite may be dwarfed as well as its host." (10).

Peronospora effusa (Grev.) Rabh.
**Chenopodium* sp. (1).
Chenopodium album (10). Dwigans; Ames, October, 1899. Hitchcock; Ames. Halsted found it on this host at Spirit Lake in 1885. Mature oöspores were found on the leaves (5).
Plantago major. Pammel; Ames, June, 1909.

Peronospora sordida B. and Br.
Scrophularia nodosa (4). Bessey; Ames, October, 1882. "Has been a good illustration of the influence of moisture on mildew. The host *Scrophularia nodosa* is a common plant on the banks of streams, especially when the slope is steep and without sod. The peronospora was frequently looked for, but it appeared in its usual abundance in only one place and this was at the bend in a stream, where the host grew close to the water" (10).

Peronospora viciae (Berk.) D.By.
Vicia Americana. Hitchcock; Ames. "Abundant in the latter part of May and early June on this host."

Peronospora trifoliorum D.By.
**Astragalus canadensis* (4).
Medicago sativa. Schultz; Postville, June, 1914.
Vicia Americana (1), (4). "Abundant early in summer. Unable to propagate well in 3 per cent sugar solution". (2). "Has heretofore been a common species upon *Astragalus canadensis* and especially on *Vicia Americana.* Upon the latter it was so abundant two years ago as to almost destroy the host in whole patches. This year it was obtained only after a long search in the moistest places in which the vetch will grow." (10).

Peronospora potentillae D.By.
Agrimonia gryposepala. Melhus; Ames, June, 1916.
Potentilla monspeliensis (4), (8). Hitchcock; Ames. Anderson; Decatur County, May, 1904. "On Potentilla sp. in autumn" (1). "Not found in 1895; local in 1894" (6). "Found only in one place, in shade of leaves of *Potentilla monspeliensis*" (8).

Peronospora euphorbiae Fckl.
**Euphorbia maculata* (4).
**Euphorbia preslii.*
Euphorbia serpyllifolia (2). Hitchcock; Jewell Junction. "Is a species which quickly diminishes in time of drought. Not uncommon in *Euphorbia maculata* in wet seasons. Scarce past two years. A new host, *E. serpyllifolia* was added last year by Mr. Hitchcock. (10).

Peronospora Arthuri Farl.
Oenothera biennis. Anderson; Decatur County, July, 1905. Melhus; Iowa City, July, 1916.

Peronospora polygoni Thuem.
Polygonum aviculare (4), (10). King; Ames, June, 1912.
Polygonum scandens (4). "Is far from common on this host. Mr. Hitchcock in May, 1887, found a few specimens of it on *P. aviculare,* thus making a new host for Iowa." (10).

Peronospora lophanthi Farl.
Agastache scrophulariaefolia (2), (10). Hitchcock; Ames. "Found for first time in this host in 1888." (10).

Peronospora alta Fckl.
Plantago major (4), (10). Pammel; Ames, June, 1909. June, 1910, June, 1917. "In 1885 very common. Has been almost entirely absent from *Plantago major* for past year." (10).
Plantago Rugelii. Pammel; Ames, October, 1909. King; Ames, 1912.

Peronospora hydrophylli Waite.
Hydrophyllum Virginicum. Pammel; Ames, June, 1914. McGregor, May, 1918. "Reported by Hitchcock on this host at Iowa City in 1888" (13).

Peronospora sparsa Berk.
Rosa sp. Sioux City, October, 1914.

Peronospora alsinearum Caspary.
Cerastium nutans (4).

Peronospora urtica (Lib.) D. By.
**Laportea canadensis* (4).

Peronospora calotheca D. By.
**Galium aparine.* Holway found oöspores in the leaves and stems of this host at Decorah, June, 1884. (13).
**Galium boreale* (4). "Frequently met with on species of *Galium.* Not found this season until October 14, when it was collected in abundance upon seedling bed straws. This seems like a clear instance of fresh-growing plants being favorable for the development of *Peronosporas.*" (10).

Peronospora leptosperma D. By.
"On wild sage" (1).
**Artemisia biennis* (4), (10).
**Artemisia ludoviciana.* Common in these last two hosts in 1895.

Peronospora ficariae Tul.
**Ranunculus repens* (4).

Peronospora violae D. By.
Viola sp. Knox; Primghar, August, 1911.

Peronospora gonolobi Lagerh.
Gonolobus laevis. Anderson; Decatur County, July, 1902.

Mucoraceae

Pilobolus crystallinus (Wigger) Tods.
"On horse dung very common in midsummer and autumn." (1).

Rhizopus nigricans Ehr.
Solanum tuberosum. Ames. "The common black mold of bread." (1). "The common decay of apples" (4). "On germinating corn" (9).

Mucor mucedo Linn.
"Common on decaying vegetable matter" (4).

Mucor racemosus Fres.
"On decaying plums and fermenting liquor."

Sporodinia grandis Link.
"On decaying toad-stools and pore fungi" (1).

Entomophthoraceae

Empusa muscae Cohn.

Musca domestica. Morrison; Ames, November, 1900. "On common flies in autumn." (4).

Entomophthora calopteni Bessey.
"This fungus is parasitic upon grasshoppers in autumn." (1). "On Rocky Mountain locust." (4).

Entomophthora radicans. Bref.
"On cabbage butterfly." (4).

INDEX OF HOSTS

Brassica arvensis
Cystopus candidus (Pers.) Lev.
Brassica campestris
Peronospora parasitica (Pers.) Tul.
Brassica nigra
Cystopus candidus (Pers.) Lev.
Peronospora parasitica (Pers.) Tul.
Capsella bursa-pastoris
Cystopus candidus. (Pers.) Lev.
Peronospora parasitica (Pers.) Tul.
Cerastium nutans
Peronospora alsinearum Caspary
Chenopodium sp.
Peronospora effusa (Grev.) Rabh.
Chenopodium album
Peronospora effusa (Grev.) Rabh.
Draba Caroliniana
Peronospora parasitica (Pers.) Tul.
Echinocystis lobata
Plasmopara australis (Speg.) Swingle
Eupatorium purpureum
Plasmopara Halstedii (Farl.) B. and dT.
Euphorbia maculata
Peronospora euphorbiae Fckl.
Euphorbia Preslii
Peronospora euphorbiae Fckl.
Euphorbia serpyllifolia
Peronospora euphorbiae Fckl.
Erigeron sp.
Plasmopara Halstedii (Farl.) B. and dT.
Galium aparine
Peronospora calotheca D.By.
Galium boreale
Peronospora calotheca D.By.
Geranium Carolinianum
Plasmopara geranii (Pk.) B. and dT.
Geranium maculatum
Plasmopara geranii (Pk.) B. and dT.
Gonolobus laevis
Peronospora gonolobia Lagerh.
Helianthus annus
Plasmopara Halstedii (Farl.) B. and dT.
Helianthus doronicoides
Plasmopara Halstedii (Farl.) B. and dT.
Helianthus grosse-serratus
Plasmopara Halstedii (Farl.) B. and dT.
Helianthus Maximiliani
Plasmopara Halstedii (Farl.) B. and dT.
Helianthus tuberosus
Plasmopara Halstedii (Farl.) B. and dT.
Hydrophyllum Virginianum
Peronospora hydrophylli Waite.
Impatiens biflora
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Impatiens pallida
Peronospora obducens Schrot.
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Lactuca ludoviciana
Bremia lactucae Regel.
Lactuca leucophoea
Bremia lactucae Regel.
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Peronospora parasitica (Pers.) Tul.
Cystopus candidus (Pers.) Lev.
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Panax quinquefolium
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Peronospora polygoni Thuem.
Polygonum scandens
Peronospora polygoni Thuem.
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Potentilla monspeliensis
Peronospora potentillae D.By.
Prenanthus albus.
Bremia lactucae Regel.

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Cystopus candidus (Pers.) Lev.
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Cystopus candidus (Pers.) Lev.
Ranunculus repens
Peronospora ficariae Tul.
Raphanus sativus
Cystopus candidus (Pers.) Lev.
Peronospora parasitica (Pers.) Tul.
Rosa sp.
Peronospora sparsa Berk.
Rudbeckia laciniata
Plasmopara Halstedii (Farl.) B. and dT.
Rudbeckia triloba
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Silphium laciniatum
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Silphium perfoliatum
Plasmopara Halstedii (Farl.) B. and dT.
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Cystopus candidus (Pers.) Lev.
Peronospora parasitica (Pers.) Tul.
Sisymbrium officinale
Cystopus candidus (Pers.) Lev.
Peronospora parasitica (Pers.) Tul.
Solanum tuberosum
Phytophthora infestans (Mont.) D.By.
Rhizopus nigricans Ehr.
Viola Americana
Peronospora vicia (Berk.) D. By.
Peronospora trifoliorum D.By.
Viola sp.
Peronospora violae D.By.
Vitis labrusca
Plasmopara viticola (B. and C.) B. and dT.
Vitis bicolor
Plasmopara viticola (B. and C.) B. and dT.
Vitis vulpina
Plasmopara viticola (B. and C.) B. and dT.
Xanthium canadense
Plasmopara Halstedii (Farl.) B. and dT.

BIBLIOGRAPHY

1. *Bessey, C. E.,* Bul. Dept. of Botany, Ia. State College, 1884.
2. *Halsted, B. D.,* Bul. Dept. of Botany, Iowa State College, 1886.
3. *Wilson, G. W.,* North American Peronosporales.
4. *Greene, W.,* Plants of Iowa. Bul. State Hort. Soc., p. 22, 1907.
5. *Pammel, L. H.,* New Fungous Diseases of Iowa; Jour. Myc. Vol. 7, p. 95.
6. *Pammel, L. H.,* and *Carver, G. W.,* Fungous Diseases of Plants at Ames, Iowa; Proc. Ia. Acad. Sci., Vol. 3, p. 140, 1895.
7. *Pammel, L. H.,* and *King, C. M..* Notes on Factors in Fungous Diseases of Plants with Records of Occurrence of Plant Diseases at Ames for a period of twenty-five years; Proc. Ia. Acad. Sci., Vol. 16, p. 41, 1909.
8. *Pammel, L. H.,* Diseases of Plants at Ames, 1894; Proc. Ia. Acad. Sci., Vol. 2, p. 201, 1894.
9. *Pammel, L. H.,* Grasses of Iowa; Bul. 54, Ia. Agr. Exp. Sta., 1890.
10. *Halsted, B. D.,* Iowa Peronosporæ and a Dry Season; Bot. Gaz., Vol. 13, p. 52, 1883.
11. *Farlow, W. G.,* Enumeration of the Peronosporæ of the U. S.; Bot. Gaz., Vol. 8, p. 305, 1888.
12. *Farlow, W. G.,* Additions to the Peronosporæ of the U. S.; Bot Gaz., Vol. 9, p. 37, 1884.
13. *Swingle, W. T.,* Some Peronosporacæ in the Herbarium of the Division of Vegetable Pathology; Jour. Myc., Vol. 7, p. 109, 1892.

CONCERNING THE CAPACITY OF FOLIAGE LEAVES TO WITHSTAND WOUNDING

ROBERT B. WYLIE

Foliage leaves are peculiarly liable to injury. From the nature of their work they are denied the protection given to older stems and larger roots. Their delicate structure not only invites insects, larvæ, and other plant eating animals, but subjects them to repeated injury by purely mechanical agencies. Observation of leaves as they are found torn and mutilated in nature shows that they possess considerable power of adjustment to wounds and injuries.

The main object of the experiments outlined below was to find out something of the power of foliage leaves to endure severe injury and the loss of larger parts, particularly their ability to get along after their major venation had been destroyed. It was hoped in this way to learn something of the ability of the minor venation to meet emergencies involving special demands on their capacity for conduction and mechanical support.

During the summer of 1920 the leaves of a number of plants growing on the campus of the Iowa Lakeside Laboratory (on the west shore of Lake Okoboji in northwestern Iowa) were subjected to various types of mutilation. The leaves employed were mainly those with pinnate venation (Figs. 49-54), though one or two with palmate major veins were used. The list most used included Lilac; Basswood (*Tilia americana* L.); Red Elm (*Ulmus fulva* Michx.); Bur Oak (*Quercus macrocarpa* Michx.); Wild Grape (*Vitis vulpina* L.); Wolfberry (*Symphoriocarpos occidentalis* Hook.); Four o'clock (*Oxybaphus nyctagineus* (Michx.) Sweet); *Solidago rigida* L.; and Milkweed (*Asclepias syriaca* L.). The latter three plants are herbaceous, while the others are woody.

These plants all stand on a somewhat sheltered hillside, sloping to the east, with some protection afforded both by topography, adjacent trees, and buildings. However, the area borders on the near-by open prairie and is in a region subjected to the drying influence of the searching winds of the open country. No attempt was made to measure the environmental factors since relative values were sought at this time rather than quantitative results.

With such diveerse conditions even in different parts of the same plant it was not thought best in this series to try to evaluate the degrees of difference. So, while note was taken of the differences between interior and exterior leaves of given plants as well as the contrasts between sun and shade leaves of the same tree, there was no attempt in this connection to get other than qualitative results.

The wounding of the leaves was carried out in part by means of a leather-punch with cutting margin of the shell thinned down and sharpened to a keen edge, and having base covered with a rubber pad. With this tool, which removed a circle of tissue 3 mm. in diameter, it was possible to excise any desired portions of a leaf or to cut out cleanly a section of a vein and its bordering blade (Figs. 49-52). Moreover, the cut edges were left so far apart that they were fully exposed to dessication and infection, thus simulating the conditions resulting from natural wounds due to leaf eating larvæ, etc.

In another series of experiments (Figs. 53, 54) slits were cut in leaves by means of a large razor, the leaf meanwhile being supported underneath by a sheet of heavy cardboard. While this left a smooth straight margin, the wounded edges, especially at the ends of the slits, were somewhat mutually protective.

Studies by the writer, as yet unpublished, outline the methods on the part of foliar organs by which they repair their wounded margins. These studies show that cicatrization of foliar wounds is slow in starting but is well advanced within ten days and that traumatic water loss, very severe at first, probably ceases in half that time. With these earlier results in mind the experiments with which this paper deals were in some cases shortened as much as possible. This knowledge, for instance, enabled one to leave mechanically weakened leaves a minimum time, thus lessening the danger of destruction from winds. Since the primary object sought was to determine the conductive efficiency of minor veins, there was no gain from further prolonging the experiment after such results were obtained. It was a matter of surprise, though, to see how successfully many badly wounded leaves sustained themselves mechanically though lacking seemingly fundamental parts.

While numerous variations of methods of wounding were tried, singly or in combination, those here discussed might be summarized as follows:

(1) Destruction of the midrib in one or more places. (2)

Cutting major lateral veins, with or without destruction of midrib. (3) Injuries to blade between the principal veins. (4) U-shaped cuts leaving peninsulas of living tissue. (5) Parallel slashes ending inside the periphery of the leaf. (6) Cuts parallel to the midrib extending through the outer end of the leaf.

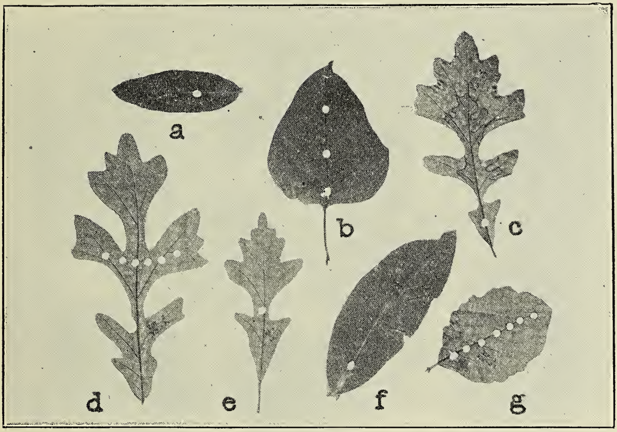

Fig. 49. Leaves with midribs interrupted in one or more places.

I. *Injuries to the midrib* (*Fig. 49*).—The midvein occupies such a prominent place in the architecture of the leaf that it was naturally supposed to be essential to the work of this organ. Trials soon established, however, that any of the broader leaves studied could get along readily with a section of the midrib removed. Leaves with broader blades seemed to thrive even after the midvein had been destroyed through practically its entire length (b, g).

The cleft leaves of oak presented difficulties for if the midrib were interrupted opposite the narrower part of the blade only a slender lateral margin was left for conduction and support. If the leaf suffered too great water loss a part of the distal area died (c). A smaller oak leaf (e), growing in a somewhat protected position, survived the loss of midvein without death of remaining tissue. Wounds in the broader portions of these leaves offered no difficulty even when lateral veins were cut (d).

In all these cases the life of considerable portions of leaf-tissue was conditioned upon conduction, for a minimum distance at least, through minor veins which were also compelled to assume increased responsibility in the mechanical support of the blade.

II. *Cutting and major lateral veins (Fig. 50).* — With the exception of the more exposed Basswood leaves (d, e), all these

Fig. 50. Leaves with one or more interruptions of major lateral veins.

under study tolerated two or more interruptions of each major lateral vein. In some of the broader leaves the midrib was also interrupted, thus disturbing the entire major venation without seeming injury to the blade. An oak leaf (Fig. 49, d) with all large veins interrupted in the wider part of the blade near middle of leaf suffered no death of tissue.

The results here confirm those of the above noted experiments indicating great capacity on the part of the islet borders for conduction. They seem able not only to carry abnormal loads but show their adaptability in that conduction may be carried on in changed direction.

III. *Injuries to blade between the major veins (Fig. 51).*— Foliage leaves are most commonly injured, whether by leaf eating insects or other agency, in the areas between larger veins. As

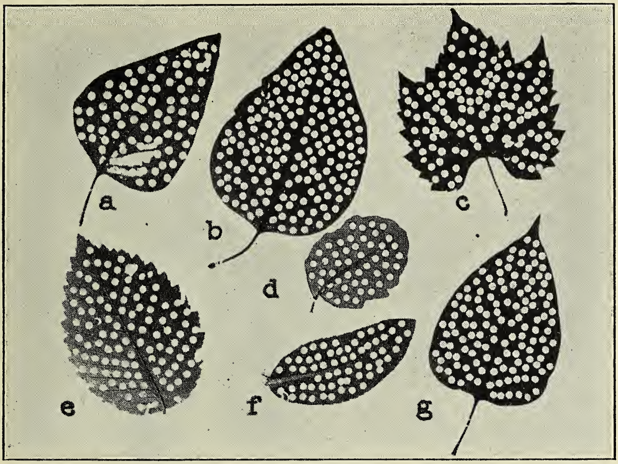

Fig. 51. Leaves with numerous wounds in the regions between major veins.

may be seen from the photographs the leaves in these experiments were severely injured.

Results indicate that considerable portions of the blade may be removed without death of remaining parts. Such injuries seem always to be local in effect and result in the loss of an almost imperceptible amount of the remaining tissue, due to drying of the wounded edges. If, however, in cutting out the blade with the punch two areas were cut out so close together as to leave an isthmus less than a millimeter in width the living tissue thus subjected to water loss from both sides in some cases died. In the case of certain Lilac leaves (b, g) one-third of the total leaf area was removed, without death of tissue. In Oxybaphus (a) the destruction of blade near base of leaf was due to the attack of a larva. Grape (c), which is very sensitive to injuries to veins, stood up well in this experiment.

Measurements showed that in certain Lilac leaves the total length of unprotected wounded leaf margin exposed along the edges of the wounds was six and one-half times the total distance around the leaf. Recalling the conditions of the experiment it becomes apparent that rarely in nature would leaves have to meet such difficult demands.

IV. *U-shaped cuts in leaves* (*Fig. 52*).—To test the efficiency

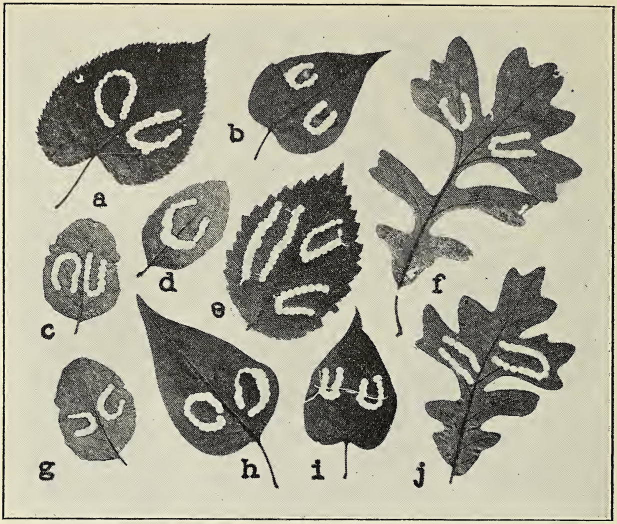

Fig. 52. Leaves with U-shaped cuts thus making unusual demands on the blade-tissue both as to amount and direction of flow.

of conduction in different parts of the blade as well as in different directions a series of U-cuts was arranged which yielded some surprising results. In preparing these experiments the leaf-punch was used which cut out a broad zone of blade around the peninsulas of living tissues, thus exposing their freshly wounded margins to the fullest effects of evaporation. In earlier attempts the projecting lobe of the blade was given mechanical support by lacing across the gap with a few stitches of fine thread (i) thus tying the lobe to adjacent portions of the blade and holding the peninsula in position. But it was soon found that such precaution was unnecessary so in all subsequent cases the lobe was left without artificial support, which greatly simplified the procedure. The U-cuts were tried on all leaves of the series except the milkweed. There was considerable variation in position, direction, and form, some having the open end of the U constricted by curving inward the arms on either side (h).

In some cases midribs or larger veins were left as leaders into the peninsulas, either directly (a), or inversely in the instances of inverted U-cuts (a, e, f). In others no large vein was left as

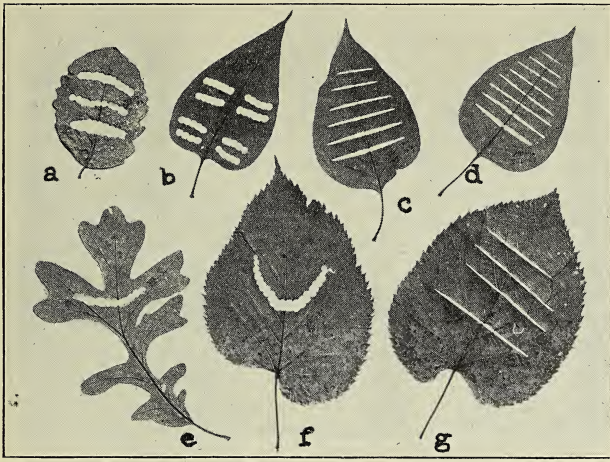

Fig. 53. Leaves with one to several slashes across the blade.

leader though one or more of the larger veins ran parallel with the longer dimension of the peninsula (h). In some the veins did not aid but were barriers because they ran across the area at various angles thus interrupting the inward flow of water (j).

The peninsulas in all cases except certain sun leaves (b) survived. The failures were associated usually with barrier veins running across the peninsulas in such way as to cut off conduction. Leaves with similar or even more severe exposure, if free from such barriers, showed no dead tissue (i). In a number of these experiments conditions were accidentally made very difficult. For example, in one of the cuts on Elm (e) a grasshopper ate out a portion of the base of the upper right hand peninsula, greatly reducing its width, and a tear due to wind narrowed the living margin outside, yet this peninsula survived.

The significant results of this series of experiments is that the minor venation of a leaf is not only sufficient to care for adjacent tissue but may be forced to accommodate large areas demanding a greatly increased flow. The direction of water movement may be readily reversed. In peninsulas free from barrier veins the area that may be sustained by a narrow isthmus of blade, without any assisting larger veins, is surprisingly large. One peninsula in Lilac (h. left) with an area of 175 sq. mm. was sustained by an isthmus only a little over one millimeter wide and without any prominent vein.

V. *Cuts ending within the periphery of the leaf.*—A. Transverse cuts, Fig. 53. In general leaves may be cut across the central portion of the blade, severing the midrib and basal major veins, without death of tissue. Even the most sensitive leaves like Vitis and Basswood (f) withstood successfully single transverse cuts through the central two-thirds of their width and interrupting all the primary venation. In Lilac (c, d), *Symphoriocarpos* (a), and Elm a series of parallel transverse cuts, separated by less than one centimeter of leaf tissue, and extending two-thirds of the distance across the blade, produced no apparent disturbance of the functions of the leaf. In Basswood (g) such wounding resulted in the death of a fan-shaped area of the blade broadest at the apex of the leaf and narrowing to a point beginning above the lowest transverse cut. As discussed below the difficulty with Basswood seems to be associated with its arrangement of secondary venation. In Oak (e) single cuts, penetrating into the opposite lobes and extending over one-half of the distance across the leaf, left the distal portion of the leaf apparently uninjured. The shape of these oak leaves did not permit a series of parallel transverse cuts.

The path of conduction, in a leaf with parallel transverse cuts, is not only greatly lengthened but is complicated by the presence of larger veins, lying across the trend of conduction. A little consideration will show the extremely difficult situations encountered by *Symphoriocarpos* (a) or Lilac (c, d).

B. Longitudinal sections or cuts. Leaves are in general less tolerant of slashes parallel to the midrib than to those at right angles to its axis, this due in part to the fact that cuts in this direction cross the major veins at a sharp angle thus leaving barriers to the movement of water along the strips. This series confirms findings of above noted experiments as to relative "sensitiveness" of different leaves. There were brought out strongly also the effects of cross veins as barriers, and the importance of adequate supply to base of any given strip of blade. If the slashes begin higher in the leaf, somewhat above the base, the results are much more successful. In these experiments Asclepias was the least able to endure wounding, with Basswood second. It was noted that in both of these there is a marked increase in the efficiency of the conduction in the marginal region.

VI. *Cuts parallel to the midrib and extending through mar-*

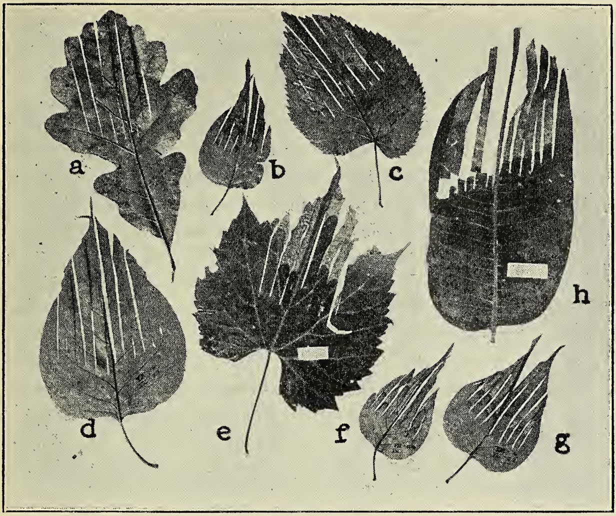

Fig. 54. Leaves with several slashes parallel to the midrib, and extending through the outer end of the leaf.

gin of blade (*Fig. 54*).—Results here are seemingly unfortunate as all except the shade leaves of Lilac (d) show death of parts of the strips. The causes of this failure are not far to seek. In the first place the leaves were robbed of a contact with a continuous marginal strip which has been shown in these experiments to possess marked efficiency for conduction. Secondly, the direction of the slashes left the major veins as barriers across the strips. Independent of these retardative features to the flow of materials, is the major difficulty due to the fact that the strip is attached at but one end, while fully exposed to double water loss both right and left. This halves the possible sources of supply and leaves the central ones interrupted by the larger veins.

A comparison of parallel strips in a given leaf reveals the importance of favorable basal supply and also the advantage of wider over narrower strips. Comparison of shade leaf (d) with sun leaves (f, g) of the same species (Lilac) reveals the influence of exposure.

Most of these leaves, and especially the more sensitive, Basswood (c), and Asclepias (h), show a marked efficiency for modified conduction in the submarginal zone. This is in part due to the absence of larger veins as barriers in this region and secondly to a convergence of the veinlets into a more or less distinct submarginal vein, running parallel to the leaf margin. Conclusions from these experiments are not definite on this point, however, as the marginal strip was injured on the inner side only, the outer side, or leaf margin, being left uninjured. As a result these outside strips were subjected to but half the possible water loss as compared with interior zones which had two cut edges. This point will be the basis of some experiments next year. Inside the marginal zones, just mentioned, there is considerable divergence of result depending upon width of strip, relation to basilar major veins, and larger veins crossing the strips.

DISCUSSION

These experimental wounds are of interest chiefly in comparison with those induced by leaf-eating insects or larvæ. In general, it would seem that the conditions imposed were often much more difficult than those likely to be encountered in nature. While leaves are often reduced to mere skeletons by such insect attacks, the period through which destruction takes place is greatly prolonged, thus permitting gradual adjustment, or it may occur only at night, allowing a number of hours for repair before the period of greater transpiration begins.

In these experiments the wounds were all made at one time, the last but a few minutes later than the first. Conditions were rendered difficult also in that the wounds were inflicted early in the day and the leaves were promptly exposed to many hours of sunshine through the period of maximum transpiration. Whatever shock the plant might experience from such wounds was also augmented by the numerous and extensive lesions made at one time. Further, it should be noted, that in most of the wounds due to natural causes only the softer portion of the blade is eaten out by insects, leaving the veins uninjured, while in most of these experiments the major veins were partly or wholly destroyed, leaving them as hindrances rather than aids to the leaf in its problem of readjustment.

Freundlich[1] has called attention to the possibility of regeneration of vascular bundles in leaves through the enlargement of the smaller veins after the larger conducting channels have been interrupted. In these experiments there was no suggestion of

1 Freundlich, H. F., Entwicklung und Regeneration von Gefäsbündeln in Blattgebilden; Jahrb. f. wis. Bot., 46:137-206, 1908.

regeneration though many leaves were critically examined by means of binocular microscope. No sections were made relative to this point in my study as such seemed unnecessary. Obviously the maximum need of water conduction occurs immediately following the wounding and before there could be any possibility of regeneration of the conducting cells or tissues. Wounded leaves generally showed within a few hours (and usually within a couple of hours) the total area that was later to turn brown, if any death of tissues resulted from the wounds. All results indicated that badly wounded leaves passed the crisis, as far as water conduction was concerned, before any cicatrization or regeneration could possibly assist, and that, this crisis safely passed, no serious difficulty was likely to be encountered on this account. Naturally subsequent cicatrization would assist in conserving water and would lessen the danger of infection.

Many experiments indicated that the larger veins, when interrupted, act as obstructions to the movement of water across them. Whenever a strip or peninsula of living blade was crossed by a section of a larger vein it suffered as compared with similar areas without such barriers. The difficulty may have been due in part to water loss from the cut ends of the large veins. On general grounds one would expect considerable leakage from the interrupted xylem strands, thus prolonging the traumatic water loss. Studies in progress show that it is very difficult for a wounded leaf to heal the cut end of a vein. These interrupted veins therefore probably caused water loss long after the margins of the wounded blade had been healed through cicatrization.

The inefficiency of the Basswood type of leaf also deserves consideration. Its uniform failure to meet difficult conditions may be due to the ladder arrangement of its major venation. It has numerous relatively large cross veins which unite at frequent intervals the main parallel lateral veins, thus enclosing rectangular groups of islets. This arrangement, however efficient it may be for normal conditions, seemed unsatisfactory for handling conduction under the modified demands of these experiments.

SUMMARY

1. The ordinary foliage leaf, of necessity a more or less delicate and unprotected structure, is so organized as to withstand serious wounds as well as losses of considerable amounts of tissue.

2. Injuries to the blade between larger veins are always local

in effect and the cut margins quickly heal. A large part of the blade may be removed at one time without disaster to the remaining portions.

3. Leaves may get along very well without midrib if there is considerable width of blade on either side to provide for conduction and mechanical support.

4. Broader leaves succeed very well without their principal veins, or even with major veins and midrib destroyed.

5. Larger veins act as barriers to conduction across them. This may be due in these experiments to loss of water from their broken ends, or to difficulty in getting water through them transversely.

6. A submarginal zone, free from larger veins, is prominent in many leaves and is efficient for conduction in all directions.

7. In some leaves the submarginal zone has developed a vein parallel to the edge of the leaf which functions for lengthwise conduction and connection of parts of blade.

8. Irregular wounds reveal a marked ability of the conductive tissues of the islet borders to adapt themselves to unusual demands both as to amount and direction of conduction.

9. Badly mutilated leaves show unexpected strength of blade, apart from all larger veins, in meeting mechanical strain.

10. The rectangular system of islet groups, bordered by larger veins, may be efficient in the uninjured leaf, but is not adapted to dealing successfully with modified conditions resulting from wounds.

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KEY TO THE FAMILIES OF FLOWERING PLANTS OF CENTRAL IOWA

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Botanizing in Iowa has always been hampered by the lack of a local flora. To identify our plants in a manual for the northeastern United States is a task for indomitable enthusiasts, or for specialists. Beside this, the keys now extant are phrased in technical language, requiring a minute knowledge of Botany and detailed dissection of specimens.

For the aid of beginners, the writers have tried to prepare a simple key to the families of plants of central Iowa. We have omitted families not known in that region. We have disregarded species and genera which do not occur in our range. For example, our key gives Gentianaceae, but provides no means for tracing Menyanthes, since that genus occurs only in the northern counties. Such examples, however, are few, and the key could be used in schools or colleges all over the state without much inconvenience.

We have provided means for tracing dioecious plants when only one kind of flower is found. A special section is devoted also to monoecious plants. It has not been possible to eliminate the counting of ovary cells, but the calls for such counting have been reduced to a minimum. The key is eminently "artificial," avowedly so. When students have learned to know a hundred families in this simple way, they should, of course, use a more technical key. In any case, the detailed descriptions of families should be looked up in a complete manual.

By way of orientation, we have prefixed a synopsis of the plant kingdom, and a key to the principal groups of plants, along lines already published in these proceedings and elsewhere. We invite criticism of the entire contribution, hoping thereby to effect such corrections as will make a thoroughly workable key.

SYNOPSIS OF THE PLANT KINGDOM

1. Thallophyta	Lower Plants
1. Myxomycetes	
2. Schizophyta	
(1) Schizophyceae	Blue-Green Algæ
(2) Schizomycetes	Bacteria
3. Flagellata	
4. Diatomaceæ	Diatoms
5. Chlorophyceæ	Green Algæ
(1) Heterocontæ	Conferva
(2) Acontæ	Spirogyra, Zygnema, Desmids
(3) Isocontæ	
a. Cellular series	Ulothrix, Draparnaldia, Pleurococcus
b. Siphonous series	Vaucheria, Cladophora
(4) Stephanocontæ	Oedogonium
6. Phæophyceæ	Brown seaweeds
7. Rhodophyceæ	Red seaweeds
8. Eumycetes	True fungi
(1) Phycomycetes	Molds
(2) Ascomycetes	Mildews, Dothidella, Taphrina, Penicillium
(3) Laboulbeniomycetes	Parasitic on insects.
(4) Basidiomycetes	Rusts, Smuts, Mushrooms, etc.
9. Lichenes	Lichens
10. Charales	
2. Embryophyta	Embryo plants
1. Atracheata	Moss Plants
(1) Hepaticæ	Scale Mosses, Marchantia, etc.
(2) Musci	True Mosses, Mnium, Hypnum,
2. Tracheata	Vascular Plants: Woody Plants
(1) Lycopsida	Lycopodium, Selaginella Equisetum
(2) Pteropsida	
1. Aspermæ	Ferns
2. Gymnospermæ	Pine, Ginkgo, Cypress, etc.
3. Angiospermæ	
1. Dicotyledoneæ	Smartweed, Bean, Sunflower, etc.
2. Monocotyledoneæ	Grass, Asparagus, Lily, Canna, etc.

KEY TO THE PRINCIPAL GROUPS OF PLANTS

1. Plants without distinction of root, stem, and leaf; no flowers (green scum, water weeds, fungi, etc.)
   1. THALLOPHYTA

1. Plants with distinct lvs., with or without roots or fls.
   2. EMBRYOPHYTA 2

   2. Small plants (to 1 dm. tall) with green lvs.; or scalelike growths on earth; or floating; without true roots or fls. (Mosses, etc.)
      1. ATRACHEATA

   2. Plants with true roots and vascular bundles; mostly with veiny lvs.
      2. TRACHEATA 3

3. Plants without fls.; herbs, propagated by spores 4
3. Plants with fls. (stamens and pistils), propagated by seeds 5

   4. Spores yellow; lvs. small; one sporangium in each axil
      2.1. LYCOPSIDA
      1. LYCOPODIALES

   4. Spores green, cottony, borne in terminal cones; stems jointed
      2.1. LYCOPSIDA
      2. EQUISETALES

   4. Spores borne on the backs of ordinary or modified lvs.
      2.2. PTEROPSIDA
      1. ASPERMÆ

5. Trees with light grey bark, and 2-lobed lvs. with fine, forked, parallel veins
   2.2. PTEROPSIDA
   2. GYMNOSPERMÆ
   5. GINKGOALES

5. Trees or shrubs with conelike fls., and needle-like, mostly evergreen lvs.
   2.2. PTEROPSIDA
   2. GYMNOSPERMÆ
   6. CONIFERALES

5. Trees, shrubs, or herbs with true fls., and seeds borne in an ovary. Pollen received on a stigma.*
   2.2. PTEROPSIDA
   3. ANGIOSPERMÆ 6

   6. Fls. usually with their parts in 5's; lvs. net-veined; stems with central pith, surrounded by a ring of wood, or vascular bundles, with growth in thickness by means of cambium; cotyledons 2.
      2.2.3.1. DICOTYLEDONEÆ

   6. Fls. usually with their parts in 3's; lvs. parallel-veined; vascular bundles scattered about in stems, without growth in thickness (cambium); cotyledon 1. All herbs except 1 prickly woody vine.
      2.2.3.2. MONOCOTYLEDONEÆ

* "Double flowers" must usually be identified by means of their single prototypes. Where doubling is due to change of stamens into petals, the key may be used by counting the inner petals as stamens.

KEY TO DICOTYLEDONEÆ

1.	Fls. crowded in dense heads surrounded by an involucre, the 5 stam. united by their anthers into a tube	134
1.	Fls. not crowded, or if so not involucrate, or the stam. not united	2
2.	Fls. with no perianth, or with only one circle, in this case arbitrarily called a calyx	4
2.	Fls. with both calyx and corolla	3
3.	Petals separate from one another	38
3.	Petals united at least at base into a tube	99
4.	Stam. and pist. in different fls. on different plants (dioecious)	5
4.	Stam. and pist. in different fls. on the same plant (monoecious)	13
4.	Stam. and pist. in the same fl. (perfect)	22
5.	Vines with opposite compound lvs.	Ranunculaceæ
5.	Vines with alternate lvs.	Vitaceæ
5.	Trees or Shrubs	6
5.	Herbs	11
6.	Lvs. opposite	8
6.	Lvs. alternate	7
7.	Shrub with 2 short spines at each node	Rutaceæ
7.	Spineless	9
8.	Twigs scaly-roughened; sep. 4; shrub	Eleagnaceæ
8.	Twigs smooth and shiny; sep. 4-12 or none; tree	Aceraceæ
8.	Twigs not shiny; bud scales downy; tree	Oleaceæ
9.	Fls. in catkins with no perianth, each in the axil of a scale	Salicaceæ
9.	Fls. with well defined perianth	10
10.	Bark aromatic to smell and taste; sep. 6	Lauraceæ
10.	Not aromatic; sep. 4	Urticaceæ
11.	Lvs. deeply palmately lobed or divided	Urticaceæ
11.	Lvs. 2-3 times divided into small lflts.	Ranunculaceæ
11.	Lvs. simple	12
12.	Lvs. entire, with 2 narrow lobes at base	Polygonaceæ
12.	Lvs. toothed, oval, pointed	Urticaceæ
13.	Trees or shrubs	14
13.	Woody vines	Vitaceæ
13.	Herbs	21
14.	Lvs. opposite	Aceraceæ
14.	Lvs. alternate	15
15.	Both stam. and pist. fls. in catkins or dense heads	16
15.	Only the stam. fls. in catkins or dense heads	19
16.	Heads of fls. globular; cal. absent	17
16.	Fls. in cylindric catkins	18
17.	Stipules early falling off	Hamamelidaceæ
17.	Stipules forming a sheath around the twig	Platanaceæ

18.	Fls. separate, each with 4 sep. (stam. 4)	Urticaceæ
18.	Fls. very small, crowded upon the scales of the catkin	Betulaceæ
19.	Lvs. pinnately compound	Juglandaceæ
19.	Lvs. simple	20
20.	Pist. fls. or groups of fls. exposed	Fagaceæ
20.	Pist. fls. enclosed in the scaly winter bud	Betulaceæ
21.	Ov. 1-celled, 1-seeded; sprawling herb	Chenopodiaceæ
21.	Ov. 3-celled; 3-seeded; erect	Euphorbiaceæ
22.	White leafless saprophyte 10-20 cm. tall	Ericaceæ
22.	Submerged aquatic	Haloragidaceæ
22.	Trees or shrubs	24
22.	Woody vines	23
22.	Herbs, not woody, or slightly so at base	28
23.	Fls. showy; sep. 4; stam. many; carp. many	Ranunculaceæ
23.	Fls. minute, green, panicled, sweet-scented	Vitaceæ
23.	Fls. large, solitary, chocolate brown, tubular curved	Aristolochiaceæ
24.	Lvs. opposite, palmately lobed or 3-parted	Aceraceæ
24.	Lvs. alternate	25
25.	Lvs. silvery with star-shaped hairs	Eleagnaceæ
25.	Lvs. not silvery	26
26.	Lvs. and twigs with aromatic odor and taste	Lauraceæ
26.	Not aromatic	27
27.	Stig. 2, large; ov. 1-celled, 1-seeded	Urticaceæ
27.	Stig. 1-4, minute; ov. 2-4 celled, 2-4 seeded	Rhamnaceæ
27.	Stig. 1; ov. 1-celled, 1-seeded; stam. 8	Thymeleaceæ
28.	Ov. inferior, the fl. coming from its upper surface (epigynous)	29
28.	Ov. superior, the fl. coming up around it (hypogynous)	30
29.	Sep. 3; stam. 6; ov. 6-celled	Aristolochiaceæ
29.	Sep. 4; stam. 4; lvs. whorled	Rubiaceæ
29.	Sep. 4; stam. 4; lvs. not whorled	Onagraceæ
29.	Stam. 5; one in front of each sepal; ov. 1-celled	Santalaceæ
29.	Stam. 5, attached between the perianth parts; ov. 2-celled	Umbelliferæ
30.	Ov. 2 or more, separate	Ranunculaceæ
30.	Ov. 1, 1-many celled	31
31.	Ov. 1-celled; stam. 9 or less	33
31.	Ov. 2-celled; stam. 2	Cruciferæ
31.	Ov. 3-celled	32
31.	Ov. 5-celled; many seeded	Crassulaceæ
31.	Ov. 5-10 celled and seeded; fr. a purple berry	Phytolaccaceæ
32.	Ov. many-seeded; lvs. whorled	Aizoaceæ
32.	Ov. many-seeded; lvs. scattered	Cistaceæ
32.	Ov. 3-seeded	Euphorbiaceæ
33.	Fls. showy; perianth tubular at base	Nyctaginaceæ
33.	Fls. individually small, insignificant	34

34. Perianth hard, scalelike, beset with scale-like bracts	Amaranthaceæ
34. Perianth soft, not scalelike; no scaly bracts	35
35. Stipules sheathing stem above node	Polygonaceæ
35. Stipules not sheathing, or none	36
36. Ov. many-seeded; plant spreading on the ground	Caryophyllaceæ
36. Ov. few-several-seeded; plant stiff, erect	Cistaceæ
36. Ov. 1-seeded	37
37. Sep. 4; style and stig. 1	Urticaceæ
37. Sep. 5 (3-5); stig. 2 (-5)	Chenopodiaceæ
38. Fls. often with pistils only or stamens only	39
38. Fls. perfect, i.e., pist. and stam. both	47
39. Tendril-bearing herbs	Cucurbitaceæ
39. Submerged aquatic with threadlike lflts.	Haloragidaceæ
39. Herbs	40
39. Woody vines	41
39. Trees and shrubs	43
40. Lvs. simple, oval; fls. minute	Euphorbiaceæ
40. Lvs. compound	Araliaceæ
41. Sep. and pet. absent when fl. is open	Vitaceæ
41. Sep. and pet. present	42
42. Lvs. simple, palmately veined	Menispermaceæ
42. Lvs. simple, pinnately veined	Celastraceæ
42. Lvs. of 3 lflts.; poisonous to touch	Anacardiaceæ
43. Lvs. opposite	Aceraceæ
43. Lvs. alternate	44
44. Lvs. simple, entire	Anacardiaceæ
44. Lvs. simple, finely toothed	Rhamnaceæ
44. Lvs. simple, palmately lobed	Saxifragaceæ
44. Lvs. of 3 lflts.	Rutaceæ
44. Lvs. once pinnately compound	45
44. Lvs. twice or thrice pinnately compound	Leguminosæ
45. Lflts. 1-3 cm. long, oval, entire	Leguminosæ
45. Lflts. 5-12 cm. long	46
46. Juice watery, ill-scented	Simarubaceæ
46. Juice of bark resinous, sticky	Anacardiaceæ
47. Stam. more than 10	48
47. Stam. not more than 10	63
48. Shrubs or trees	49
48. Herbs	55
49. Ov. inferior or mostly so(epigynous or perigynous)	50
49. Ov. obviously superior (hypogynous)	52
50. Lvs. opposite	51
50. Lvs. alternate; carp. 3-many	Rosaceæ
50. Lvs. alternate; carp. 2	Saxifragaceæ
51. Fls. white	Saxifragaceæ
51. Fls. chocolate brown	Calycanthaceæ

52. Sepals 3	53
52. Sepals 5 (or 4)	54
53. Fls. chocolate brown; carp. 2-5	Anonaceæ
53. Fls. pink, white or yellowish; carp. many, in a conelike head	Magnoliaceæ
54. Stam. on the edge of a cup- or saucer-shaped receptacle	Rosaceæ
54. Stam. stalks united into a tube around the style	Malvaceæ
54. Stam. attached beneath the ovary	Tiliaceæ
55. Ov. 1, 1-celled	56
55. Ov. 1, 2-many celled	60
55. Ovaries several	62
56. Seeds minute, attached to base of ov.; stig. 2-8; sep. 2	Portulacaceæ
56. Seeds attached all over inside of ov.	Papaveraceæ
56. Seeds attached to one side of ov.	57
56. Seeds attached to wall of ov. in 2 opposite rows	58
56. Seeds attached to wall of ov. in 3-5 rows	59
57. Stig. 1; fls. regular, white	Berberidaceæ
57. Fl. with a long spur behind	Ranunculaceæ
58. Sep. 2; juice colored	Papaveraceæ
58. Sep. 4; juice watery	Capparidaceæ
59. Lvs. with minute transparent dots	Hypericaceæ
59. Lvs. without transparent dots	Cistaceæ
60. Aquatic; roots under water	Nymphæaceæ
60. Terrestrial	61
61. Stam. stalks united into a columnar tube	Malvaceæ
61. Stam. separate from each other	Rosaceæ
62. Stam. attached to a flat or cup-shaped calyx	Rosaceæ
62. Stam. attached to stem between pet. and pist.	Ranunculaceæ
63. Stam. 6, of which 4 are longer and 2 shorter; or only 2	Cruciferæ
63. One stam. in front of each pet.	64
63. Stam. between the pet., or more numerous	66
63. Stam. 6, in 2 sets of 3, their stalks often united	Fumariaceæ
64. Woody vines; calyx minute	Vitaceæ
64. Herbs or shrubs; petals rolled in from tip	Rhamnaceæ
64. Herbs or shrubs; pet. flat or curving around the bud	65
65. Sep. 2; pet. 5	Portulaccaceæ
65. Sep. 5; pet. 5; stig. 1	Primulaceæ
65. Sep. 6, with 2-6 extra scales (bracts); stam. 6	Berberidaceæ
66. Ov. wholly superior (hypogynous)	67
66. Ov. wholly or mostly inferior (perigynous or epigynous)	92
67. Ov. 2 or more, wholly or mostly separate	68
67. Ov. 1, simple or compound	73

68.	Stam. united with the thick united stig.	Asclepiadaceæ
68.	Stam. free from each other and from the pist.	69
69.	Stam. on the axis of the fl., not on the calyx	70
69.	Stam. attached to calyx	72
70.	Lvs. very thick, fleshy	Crassulaceæ
70.	Lvs. thin, with fine transparent dots	Rutaceæ
70.	Lvs. thin, not dotted	71
71.	Trees; lvs. pinnate, large	Simarubaceæ
71.	Herbs; ov. several, each with stig.	Ranunculaceæ
71.	Herbs; style 1; stig. and ov. 5-lobed	Geraniaceæ
72.	Stipules present	Rosaceæ
72.	Stipules absent	Saxifragaceæ
73.	Fls. radially symmetrical, the petals all alike, and sepals all alike	74
73.	Fls. 2-sided, the petals unlike, or sepals unlike, or reduced in number	89
74.	Trees, shrubs, or woody vines	75
74.	Herbs	81
75.	Lvs. alternate	76
75.	Lvs. opposite	78
76.	Woody vines	77
76.	Shrubs with pinnately compound lvs.	Anacardiaceæ
77.	Lvs. simple	Celastraceæ
77.	Lvs. of 3 lflts.; poisonous to touch	Anacardiaceæ
78.	Trees of large size	80
78.	Shrub or small tree (to 3 cm. thick)	79
79.	Lvs. undivided, oval	Celastraceæ
79.	Lvs. of 3 lflts.	Staphyleaceæ
80.	Lvs. pinnately compound	Leguminosæ
80.	Lvs. not compound	Aceraceæ
81.	White, leafless saprophyte, 10-20 cm. tall	Ericaceæ
81.	Green plants rooting in ordinary fashion	82
82.	Lvs. with fine transparent dots, as if punctured	Hypericaceæ
82.	Lvs. not transparent-dotted	83
83.	Sepals all separate from each other	84
83.	Sepals united at base into a cup	87
84.	Ov. 1-celled	85
84.	Ov. 5 or 10-celled	86
85.	Seeds in two rows on sides of ov.; lvs. alternate	Capparidaceæ
85.	Seeds on a free column at center of ov.; lvs. opposite	Caryophyllaceæ
86.	Lvs. narrow, entire	Linaceæ
86.	Lvs. of 3 notched lflts.	Oxalidaceæ
86.	Lvs. large, lobed and toothed, hairy	Geraniaceæ
86.	Lvs. round or oval, finely toothed	Ericaceæ

87.	Ov. half inferior (perigynous)	Saxifragaceæ
87.	Ov. wholly superior (hypogynous)	88
88.	Petals attached between sepals at top of calyx cup	Lythraceæ
88.	Petals attached to stem within base of calyx cup	Caryophyllaceæ
89.	Trees with large palmately compound lvs.	Hippocastanaceæ
89.	Not as above	90
90.	Ov. 1-celled	91
90.	Ov. 2-celled, 2-seeded	Polygalaceæ
90.	Ov. 5-celled, several seeded; stems transparent	Balsaminaceæ
91.	Ov. with 1 row of seeds; fls. mostly shaped like a sweet pea	Leguminosæ
91.	Ov. with 2 opposite rows of seeds; sep. and pet. 4	Capparidaceæ
91.	Ov. with 3 rows of seeds; fl. violet or pansy shaped	Violaceæ
92.	Tendril-bearing vines	Cucurbitaceæ
92.	Not tendril-bearing	93
93.	Ovules and seeds more than 1 in each cell	94
93.	Ovules and seeds only 1 in each cell	96
94.	Stam. attached to calyx	95
94.	Stam. attached to a flat disc which covers the ov.	Celastraceæ
95.	Stam. 4 or 8; ov. long	Onagraceæ
95.	Stam. 5 or 10; ov. broad	Saxifragaceæ
96.	Stam. 5-10	97
96.	Stam. 2, 4, or 8	98
97.	Trees or shrubs; lvs. simple	Rosaceæ
97.	Trees or shrubs; lvs. compound	Araliaceæ
97.	Herbs; fr. berry-like, juicy	Araliaceæ
97.	Herbs; fr. dry, splitting into 2 parts	Umbelliferæ
98.	Shrubs; style and stig. 1	Cornaceæ
98.	Shrubs; stig. more than 1	Hamamelidaceæ
98.	Herbs; style 1	Onagraceæ
98.	Fine leafed aquatic; stig. 4	Haloragidaceæ
99.	Ov. superior (hypogynous), in center of fl. and separate from perianth	100
99.	Ov. inferior (epigynous), appearing below perianth as a swelling at apex of stalk	127
100.	Stam. more numerous than lobes of corolla	101
100.	Stam. as many as corolla lobes, and directly in front of them	105
100.	Stam. between the corolla lobes, or fewer than the lobes	106
101.	Trees; stam. attached to base of corolla; styles 4	Ebenaceæ
101.	Herbs	102
102.	Petals all alike	103
102.	Petals very different from one another	104

103.	Stam. 5-10, separate	Oxalidaceæ
103.	Stam. many, their stalks united into a tube	Malvaceæ
104.	One or two pet. sac-like; stam. 6, in 2 sets	Fumariaceæ
104.	Fl. sweet-pea shaped; stam. 10, their stalks united	Leguminosæ
104.	Stam. 4-8, in 1 or 2 groups; pet. 3	Polygalaceæ
105.	Styles 5: fl. pink or white	Plumbaginaceæ
105.	Style 1: fl. yellow or pink	Primulaceæ
106.	Corolla lobes all alike (regular)	107
106.	Corolla lobes different from one another	122
107.	Stam. as many as corolla lobes	108
107.	Stam. fewer than corolla lobes	118
108.	Ov. 2: stig. often united	109
108.	Ov. deeply 4-lobed	110
108.	Ov. 1, not deeply lobed	111
109.	Stam. not united, often touching	Apocynaceæ
109.	Stam. united with each other and with stigma	Asclepiadaceæ
110.	Lvs. alternate	Borraginaceæ
110.	Lvs. opposite	Labiatæ
111.	Lvs. entire, all from the ground; fls. in narrow spikes; corolla small, dry and hard	Plantaginaceæ
111.	Lvs. some or all on the stem	112
111.	Leafless, yellow, twining parasite	Convolvulaceæ
112.	Ov. 1-celled	113
112.	Ov. 2-10 celled; herbs with stam. on tube of corolla	114
113.	Lvs. entire, perfectly smooth	Gentianaceæ
113.	Lvs. lobed or compound, hairy	Hydrophyllaceæ
114.	Stam. 4; lvs. opposite	Verbenaceæ
114.	Stam. 5, or rarely more	115
115.	Fr. 2-6 seeded	116
115.	Fr. many-seeded, dry or juicy	Solanaceæ
116.	Twining vines; corolla showy	Convolvulaceæ
116.	Not twining	117
117.	Fl. white, solitary, 4-5 cm. long; stig. 2	Convolvulaceæ
117.	Fl. 1-2 cm. long, in groups; stig. 3	Polemoniaceæ
117.	Fl. 0.5-2 cm. long, in groups; stig. 2	Hydrophyllaceæ
118.	Stam. 4, in pairs	119
118.	Stam. 2	120
119.	Corolla blue, the tube 2.5-4 cm. long; ov. many seeded	Acanthaceæ
119.	Corolla tube 2-10 mm. long; ov. 2-4 seeded	Verbenaceæ
120.	Ov. deeply 4-lobed	Labiatæ
120.	Ov. 2-celled, not 4-lobed	121
121.	Herbs with leafy stem	Scrophulariaceæ
121.	Trees or shrubs	Oleaceæ
122.	Stam. with anthers 5, attached to corolla	123
122.	Stam. with anthers 2 or 4	124

123.	Stalks of stam. wooly	Scrophulariaceæ
123.	Stalks of stam. not wooly	Solanaceæ
124.	Trees or woody vines	Bignoniaceæ
124.	Low, yellowish, leafless parasite	Orobanchaceæ
124.	Submerged aquatic, with threadlike lflts. bearing tiny pouches	Lentibulariaceæ
124.	Ordinary, terrestrial, leafy herbs	125
125.	Ov. not deeply 4-lobed	126
125.	Ov. deeply 4-lobed; lvs. opposite	Labiatæ
126.	Ov. 1-celled, 1-seeded; fr. turned downward	Phrymaceæ
126.	Ov. 2-celled, many seeded	Scrophulariaceæ
126.	Ov. 2-4 celled, 2-4 seeded; fr. not turned downward	Verbenaceæ
127.	Tendril bearing herbaceous vine	Cucurbitaceæ
127.	Tendrils none	128
128.	Stam. separate from one another	129
128.	Stam. united by their anthers into a ring or tube	134
129.	Fls. in dense heads surrounded by an involucre	130
129.	Fls. separate, or if crowded, without involucre	131
130.	Anthers parallel and touching; often monoecious; ov. 1-celled	Compositæ
130.	Anthers wide apart; ov. 1-celled	Dipsaceæ
130.	Anthers wide apart; ov. 2-celled	Rubiaceæ
131.	Stam. free from corolla or nearly so, as many as its lobes; stipules none; juice milky	Campanulaceæ
131.	Stam. attached to corolla tube	132
132.	Stam. 1-3, fewer than corolla lobes	Valerianaceæ
132.	Stam. 4-5; lvs. opposite or whorled	133
133.	Lvs. opposite, without stipules	Caprifoliaceæ
133.	Lvs. opposite with stipules, or whorled	Rubiaceæ
134.	Fls. separate, with evident calyx and corolla	Lobeliaceæ
134.	Fls. in dense heads surrounded by an involucre; calyx reduced to hairs, scales or zero	Compositæ

KEY TO MONOCOTYLEDONEAE

1.	Fls. minute, in chaffy bracts or scales without a 3-parted perianth	2
1.	Fls. not in chaffy bracts	3
2.	Stems hollow, cylindrical; lvs. 2-ranked; fls. 2-bracted	Gramineæ
2.	Stems solid, triangular; lvs. 3-ranked; fls. 1-bracted	Cyperaceæ
3.	Aquatic plants	4
3.	Terrestrial plants	8
4.	Leafless plants. Tiny, floating bodies (1-3 mm.)	Lemnaceæ
4.	Leafy plants	5

5.	Lvs. floating or submerged	Potamogetonaceæ
5.	Lvs. not floating or submerged	6
6.	Lvs. linear with no distinction between stalk and blade. Fls. without petals, in heads	7
6.	Fls. with petals, in racemes or panicles	Alismataceæ
7.	Heads long and narrow	Typhaceæ
7.	Heads globular	Sparganiaceæ
8.	Fls. stalkless on a thick axis forming a spike	9
8.	Fls. not on thick axis	10
9.	Spike cylindric with seed-bearing fls. at base and pollen-bearing fls. above; axis woody	Typhaceæ
9.	Axis of spike fleshy, soft	Araceæ
10.	Climbing or twining stems	11
10.	Non-twining stems	12
11.	Fls. small in racemes or panicles	Dioscoreaceæ
11.	Fls. small, green, in globular umbels	Liliaceæ
12.	Fls. greenish or brown, chaffy; lvs. less than 5 mm. wide or none	Juncaceæ
12.	Fls. with conspicuous perianth	13
13.	Ov. inferior, appearing below perianth as a swelling at apex of stalk	14
13.	Ov. superior, in center of fl. and separate from perianth	19
14.	Lvs. grasslike, 5 mm. or less wide	15
14.	Lvs. broader than 5 mm.	16
15.	Fls. yellow, 1-2 cm. across	Amaryllidaceæ
15.	Fls. blue or white; if yellow, 4-6 cm. long	Iridaceæ
16.	Lvs. with one edge toward stem; stam. 3	Iridaceæ
16.	Lvs. with a flat side toward stem	17
17.	Anther-bearing stamens 6	Amaryllidaceæ
17.	Anther-bearing stamens 1 or 2	18
18.	Plants 6-20 dm. tall; lvs. 1.5 dm. wide or more; cult.	Cannaceæ
18.	Plants 1-10 dm. tall; lvs. 8 cm. or less wide. Native	Orchidaceæ
19.	Fls. with green sepals	20
19.	Fls. with sepals and petals colored alike	Liliaceæ
20.	Stems leafy; fls. clustered	Commelinaceæ
20.	Stems naked, with three lvs. and 1 fl. at top	Liliaceæ

GRINNELL COLLEGE
DEPARTMENT OF BOTANY

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