PROCEEDINGS

OF THE

Iowa Academy of Science

FOR 1909

VOLUME XVI

EDITED BY THE SECRETARY

PUBLISHED BY THE STATE

DES MOINES
EMORY H. ENGLISH, STATE PRINTER
1909

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LETTER OF TRANSMITTAL.

Des Moines, Iowa, July 20, 1909.

To His Excellency, Beryl F. Carroll, Governor of Iowa:

In accordance with the provisions of title 2, chapter 5, section 136, code, 1897, I have the honor to transmit herewith the proceedings of the twenty-third annual session of the Iowa Academy of Science and request that you order the same to be printed.

Respectfully submitted,

L. S. Ross,

Secretary Iowa Academy of Science.

OFFICERS OF THE ACADEMY.

1908.

President—SAMUEL CALVIN.
First Vice-President—F. F. ALMY.
Second Vice-President—S. W. BEYER.
Secretary—L. S. ROSS.
Treasurer—H. E. SUMMERS.

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Elective—R. B. WYLIE, L. BEGEMAN, D. W. MOREHOUSE.

1909.

President—FRANK F. ALMY.
First Vice-President—G. L. HOUSER.
Second Vice-President—A. C. PAGE.
Secretary—L. S. ROSS.
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EXECUTIVE COMMITTEE.

Ex-officio—FRANK F. ALMY, G. L. HOUSER, A. C. PAGE, L. S. ROSS GEORGE F. KAY.
Elective—SAMUEL CALVIN, N. KNIGHT, C. O. BATES.

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NUTTING, C. C.	1890-92
PAMMEL, L. H.	1893
ANDREWS, L. W.	1894
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HALL, T. P.	1896
FRANKIN, W. S.	1897
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NORTON, W. H.	1900
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FINK, BRUCE	1903
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CALVIN, SAMUEL	1908

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Wheat, G. G............Emmetsburg
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CORRESPONDING MEMBERS.

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Arthur, J. C....Purdue University, Lafayette, Ind.
Bain, H. F....University of Illinois, Urbana, Ill.
Ball, C. R....Department of Agriculture, Washington, D. C.
Ball, E. D....State Agricultural College, Logan, Utah
Barbour, E. H....State University, Lincoln, Neb.
Bartsch, Paul....Smithsonian Institution, Washington, D. C.
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Leonard, A. G....Grand Forks, N. Dak.
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McGee, W. J....Bureau of Ethnology, Washington, D. C.
Meek, S. E....Field Columbian Museum, Chicago, Ill.
Miller, B. L....Bryn Mawr, Pa.
Mills, S. J....Denver, Colo.
Newell, Wilmon....Capitol Building, Atlanta, Ga.
Osborn, Herbert....State University, Columbus, Ohio
Owens, Eliza....Bozeman, Mont.
Patrick, G. E....Department of Agriculture, Washington, D. C.
Price, H. C....State University, Columbus, Ohio
Read, C. D....Weather Bureau, Sioux City
Repp, J. J....Philadelphia, Pa.
Savage, T. E....Urbana, Ill.

Sirrine, Emma...Dysart, Iowa
Sirrine, F. A..............................124 South Ave., Riverhead, New York
Spencer, A. C......................U. S. Geological Survey, Washington, D. C.
Todd, J. E...Lawrence, Kan.
Trelease, William...............Missouri Botanical Gardens, St. Louis, Mo.
Udden, J. A..Rock Island, Ill.
Weems, J. B...Alleghany, West Va.
Winslow, Arthur...Kansas City, Mo.
Youtz, L. A...New York City, N. Y.

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PROCEEDINGS OF THE

Twenty-Third Annual Session of the Iowa Academy of Science

The meetings of the Twenty-third Annual Session of the Iowa Academy of Science were held at the State University, Iowa City, in room 107, Natural Science Building, on April 30 and May 1, 1909.

In the business meetings the following matters of general interest were presented:

REPORT OF THE SECRETARY.

To the Members of the Iowa Academy of Science:

The twenty-second annual meeting of the Iowa Academy of Science was held at Iowa State Normal School, Cedar Falls, on May 1 and 2, 1908. The following fellows and members were in attendance: Messrs. Almy, Arey, Bailey, Bates, Bartholomew, Begeman, Bennett, Cable, Calvin, Chapman, Crawford, Guthe, Hersey, Jenner, Kay, Kinney, Morehouse, Newton, Nutting, Page, Pammel, Rockwood, Ross, Shimek, Smith, Stookey, Summers, Tilton, Walters, Wheat, Wilson, making a total attendance of thirty-one.

On Friday evening, May 1st, Professor John L. Tilton, gave the president's address on "Science Required for a General Education." Because of physical condition, Professor T. C. Chamberlain who was expected to give the evening lecture, found it necessary to send his co-worker, Professor Moulton, who gave an address on "Old and New Theories on the Formation of the Earth."

The membership of the Academy is slowly increasing. Four names were added to the list of fellows, and twelve to the list of members. This is not as large an increase in membership as in the preceding year. It has been some time since names were added to the Academy Council. At the last meeting fourteen members of the council were in attendance. The secretary recommends the increase of the size of the council. An amendment to the constitution was proposed instituting a life membership. According to instruction the secretary sent due notice of the proposed amendment to the fellows of the Academy. A recommendation was adopted with reference to the awarding of an annual prize for meritorious scientific research work done in Iowa. Arrangement for the awarding of the prize was left to the executive committee. Letters were sent to the members of the committee and the replies received were at such variance that the secretary at once abandoned the hope of formulating any practicable method of awarding a prize. Two members expressed themselves as unfavorable to the idea of a prize, two suggested tentative plans and the others thought the task almost hopeless. Hence no plan for the awarding of a prize is reported.

Section 4 of the constitution reads as follows: "An entrance fee of $3.00 shall be required of each fellow, and an annual fee of $1.00 due at each annual meeting after his election. Fellows in arrears for two years, and failing to respond to notification from the treasurer, shall be dropped from the Academy roll." Since the associate members have the same privileges as the fellows with reference to the publications, it seems as though the constitution should provide for the payment of fees of some amount by such members.

It is not necessary to call the attention of the Academy to the fact that the publication of Volume XV of the proceedings was delayed. Sometimes it is impossible for an author to read and return proof promptly, and occasionally such delays are sufficiently great that work considered more pressing by the printer demands and receives attention, thus interfering with work upon the proceedings. It will expedite matters much if all authors will find it possible to return proof immediately upon receiving it. The state printer thinks nothing need interfere with his work on Volume XVI during the coming summer.

There is a healthy interest manifest on the part of the Academy in the work that is being done. Scientists not connected with the Academy seem to recognize its value. More requests than usual have been received during the year for reprints and for volumes of the proceedings. The Academy is accomplishing the purpose of its existence. A commendable result other than the purely scientific is being realized; that is, the development of the feeling of fellowship among the scientists of the state. This alone, if no other results were obtained, would justify the existence of the Academy.

Respectfully submitted,
L. S. Ross, *Secretary.*

REPORT OF THE COMMITTEE ON MEMBERSHIP.

NAMES PROPOSED FOR FELLOWS.

O. J. Fay, Des Moines; Laenas G. Weld, Iowa City; E. B. Watson, Ames.

Transferred from members, H. S. Fawcett, Gainesville, Fla.; Clarence D. Learn, Clermont; C. E. Seashore, Iowa City.

NAMES PROPOSED FOR MEMBERS.

Bert Gose, Pleasantville; L. D. Weld, Cedar Rapids; Ellis B. Stauffer, State Center; Miss Elda Kemp, Marion; E. O. Heuse, Fayette; Thompson Van Hyning, Des Moines; B. O. Wolden, Wallingford; Miss Ada Hayden, Ames; Royal E. Jeffs, Ames; Lester P. Fagen, Des Moines; A. S. Begg, Des Moines; Harry R. Woodrow, Des Moines; Mrs. Gertrude B. Phillips, Grinnell; John T. Buchholz, Mt. Pleasant; Fred A. Fish, Ames; Samuel W. Griser, Independence; Joseph H. Neff, Fayette; J. W. Robinson, Grand River; Jesse A. Baker, Indianola; Albert Kuntz, Iowa City; R. S. Webster, Ames; Miss Florence Richardson, Des Moines.

AMENDMENT TO THE CONSTITUTION.

The following proposed amendment was presented to the Academy in due form and was adopted.

Insert after section 3, (4) "life members chosen from fellows."

In section 4, after the words, "his election," "a person may become a life member on the payment of $7.00 after his election as a fellow, the transfer to be made by the treasurer."

"That said life membership fees be invested and only the interest of the same be used for current expenses of the Academy."

The following by-law was adopted at the meeting of 1907.

"That hereafter a committee on membership be appointed by the incoming president at the meeting at which he is elected, which committee shall serve until their successors are appointed."

TREASURER'S REPORT.

RECEIPTS.

Cash on hand, April 30, 1908	$174.83	
Dues and initiation fees	150.90	
Sale of proceedings	9.96	
Interest on deposits	8.08	—$343.77

EXPENDITURES.

Expenses of lecture, 22d meeting	$ 30.00	
Programs of 22d meeting	3.00	
Binding, reprints, etc., Proceedings of 21st meeting	68.35	
Postage and incidental expenses of secretary	16.57	
Honorarium of secretary	25.00	
Cash on hand, April 30, 1909	200.85	—$343.77

Respectfully submitted,
H. E. Summers, *Treasurer.*

OFFICERS FOR THE YEAR 1909-10.

President	Frank F. Almy
First Vice-President	G. L. Houser
Second Vice-President	A. C. Page
Secretary	L. S. Ross
Treasurer	George F. Kay

EXECUTIVE COMMITTEE.

Ex-officio..Frank F. Almy, G. L. Houser, A. C. Page, L. S. Ross, George F. Kay

Elective..............Samuel Calvin, N. Knight, C. O. Bates

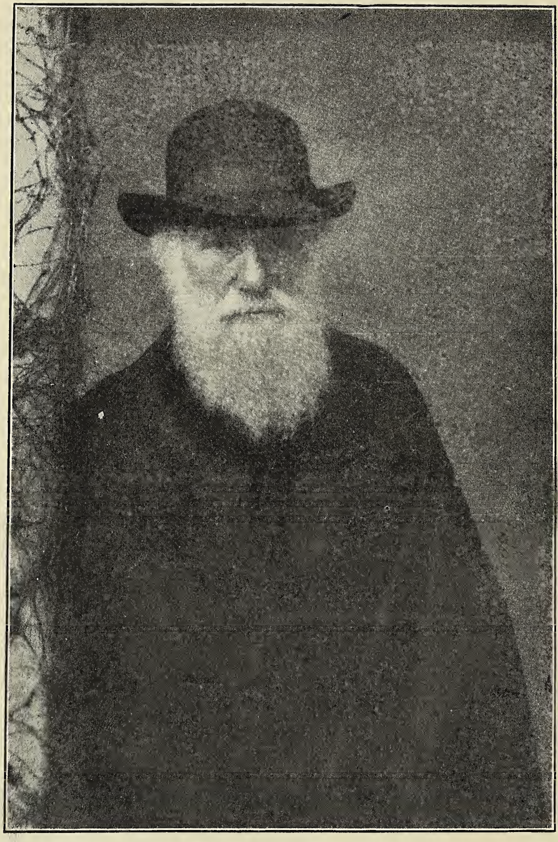
PROGRAM OF THE IOWA ACADEMY OF SCIENCE.

The President's address, by Professor Samuel Calvin, on "The Work of the Iowa Geological Survey," and the lecture by Professor William A. Locy on "The Service of Zoology to Intellectual Progress," were given in the Physics Lecture room at 7:30 p. m. Friday. Before the beginning of the evening program Professor Seashore gave demonstrations of the "Tonoscope" in his laboratory.

PROGRAM.

In Physics Lecture Room, 1:30 P. M., Friday, April 30th.

1. Comet C 1908 (Morehouse)............................D. W. Morehouse
2. The Asteroid, 1906, W. E...............................Ellis B. Stauffer
3. Further Studies of the Eastern Nebraska Flora..........Charles E. Bessey
4. The Polyporaceæ of Fayette, Iowa......................Guy West Wilson
5. Some Parasitic Polyporaceæ.................................C. D. Learn
6. An Anatomical Study of the Roots and Rhizomes of a Few Weeds.... ....L. H. Pammel and Estelle D. Fogel
7. The More Important Factors Concerned in the Production of Plant Diseases.......................L. H. Pammel and Charlotte M. King
8. Plant Distribution in Iowa in Relation to Geologic Formations...B. Shimek
9. The Sand-Dune Flora of Iowa.................................B. Shimek
10. The Flora of Iowa Rock...............................Robert B. Wylie
11. Notes on Spore Formation in Ulva......................Robert B. Wylie
12. Slime Moulds of the Yosemite.......................Thomas H. McBride
13. Okoboji Laboratory (Short Talk)....................Thomas H. McBride
14. Some Features of Iowa Ground Waters. II..............W. S. Hendrixson
15. The Training of the Technical Chemist (read on invitation)..J. S. Staudt
16. The Influence of Copious Ingestion of Water (read on invitation).... ....Stella A. Hartzell
17. The Estimation of Arsenic and Cobalt in Smaltite......Nicholas Knight
18. An Analysis of the Fruit of Viburnum Nudum..........Nicholas Knight
19. The Action of Manure on a Certain Iowa Soil................E. B. Watson
20. Significance of Thrust-Planes in the Great Basin Ranges..Charles R. Keyes
21. Orotaxial Correlation of Geologic Terranes and Diastrophism......... ....Charles R. Keyes
22. Carbonic Column of the Rio Grande Region..............Charles R. Keyes
23. A Hysteresis Curve................D. W. Morehouse and Harry Woodrow
24. The Googler Primary Cell.................................Harry Woodrow
25. On the Use of the Balance.................................LeRoy D. Weld
26. The Fifth and Seventh Cranial Nerves of Plethodon Glutinosus...... ....H. W. Norris
27. Hydroids as Ornamental Plants.............................C. C. Nutting
28. Arterio-Sclerosis ....W. E. Sanders
29. Birds of Polk County, Iowa..............................Lester P. Fagen
30. The Migration of Nervous Elements into the Dorsal and Ventral Nerve-Roots of Pig-Embryos (Introduced by Prof. Gilbert L. Houser).... ....Albert Kuntz
31. The Unios of the Muscatine County Loess......................B. Shimek
32. Some Observations on the Embryology of Chironomus......W. N. Craven



Darwin

RESOLUTIONS ON DARWIN.

It is fitting that the Iowa Academy of Science should, in some way, spread on the minutes of its proceedings, its estimate of what science owes to the work of Charles Darwin; the centenary of whose birth occurred on the 12th of February, 1909.

Darwin's contribution to science was two-fold: in the first place it consisted of additions, the result of research, additions made directly to the body of the knowledge of his time; secondly, it consisted in a singular impulse to natural history study, an impulse destined to be long-lasting as science itself.

He possessed that singular breadth of mind and view that enabled him to look upon all nature as one; at least in the fascinating interest attaching to her wondrous operations; but in this very comprehensiveness, his mind became possessed at last by one idea, a universality, difficult for some men yet to understand. He turned from one department of the natural world to another with an eagerness and apprehension absolutely impartial. To him all things were plastic. The world-shaping coral reefs rested not, but were by him associated with the phenomena of life; the barnacles or cirripeds were interesting to him not in themselves alone, but because of their wonderful departure from the habits of all their kin in adaptations almost unparalleled. All familiar domestic plants and animals charmed him by their pliancy, their obedience to the will of man; until at last there rose upon his vision the movement of the whole living world, the absolute rhythm with which all living things keep step to the changes of time and chance. Even the continents and islands, rising and dipping light on the waters, proclaim obedience to the self-same laws which guide the thistle-down in its airy flight across the sun-lit fields, or poise the humming bird in gauzy equilibrium before a summer flower. When he reached that view, geology, zoology, botany, lost their boundaries while the child of nature followed everywhere one shining silken clue which bound for him all things present and all things past in one unfailing and unbroken series.

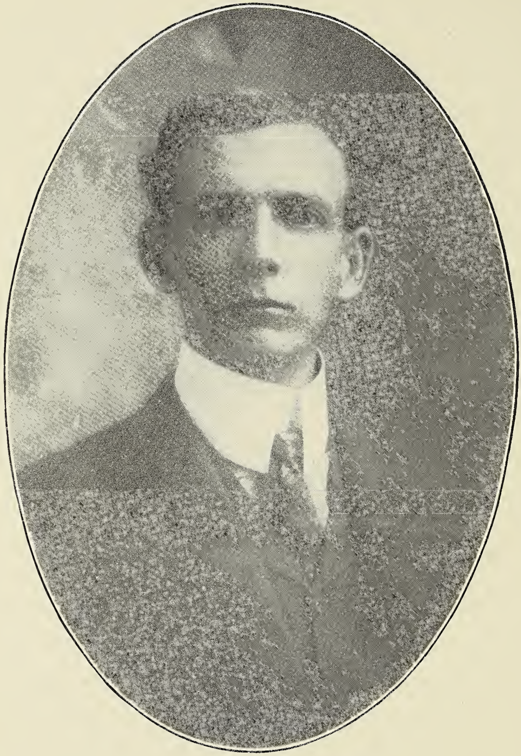
We are, accordingly, not surprised at the themes of Darwin s books: the Volcanic Island, the Fossil Cirripeds, the Geology of South America, the Birds and Plants of the Galapagos, Domesticated Plants and Animals, the Origin of Species, the Fertilization of Orchids, Twining Plants. Even at the last, the insignificant earthworm became his theme; in the unrivalled comprehensiveness of his scheme and vision, there is nothing great of earth, in Nature, nothing small.

The men of this quiet day have small suspicion of the intellectual ferment of fifty years ago. The commercial excitement of these times does not compare with it. Had Darwin by some magic touch kindled a flame on the floor of every college, of every lecture-room, of every school house, of every church, in Christendom he had not excited greater astonishment or more vigorous and wide-spread disputation.

As early as March, 1860, Asa Gray, the foremost botanist of this country, was constrained to come to the defense of the author of the origin of species, his old-time correspondent and friend, by a series of papers which should allay the excitement of the country and the resentment of men who could not at all understand the position of the greatest naturalist among the sons of men.

Modern biologic study has brought forth a wealth of material, especially statistical or quantitative study of variations, experimental morphology and physiology, as the results of Darwin's work. Some of these writers have endeavored to make light of Darwinism. New truths are added to the old and new evidences of the truth of Darwinism is being confirmed. Some phases of Darwinism are discredited but the theory of organic evolution is practically accepted by all working biologists. The theory of descent, though worked out, in part, by other naturalists before him, needed a Darwin to correlate the facts and marshal them together in order to construct a theory which would last as long as science should engage the attention of man. It was not a speculative philosophy put forth in his book on the origin of species, but one of the most remarkable scientific works ever published, his conclusions were based on sound principles and reasoning after a large number of observations had been made. In this way, the theory of descent came to be accepted by working naturalists. His work opened up a new field in biological research. No other scientific work perhaps so influenced the thought of his day or of our day as his epoch-making work on the "Origin of Species," published in 1859.

T. H. Macbride,
L. H. Pammel.



W. N. Craven.

NECROLOGY.

MR. W. N. CRAVEN.

Mr. W. N. Craven, an Associate Member of the Iowa Academy of Sciences, was born near Indianola, Iowa, December 24, 1868. He was graduated from Simpson College in 1901. After three years of teaching in Iowa he was obliged by failing health to remove to Canon City, Colorado, where he resided till the time of his death, April 26, 1909.

In 1903 Mr. Craven presented the accompanying thesis in connection with work at Simpson College. It was his intention at the time to present the paper at a university later as an evidence of previous work when seeking admission to a graduate school, but his failing health soon necessitated a change in plans. His paper is now presented to the Academy partly in recognition of the quality of his work and partly that the results of his work may be of use to other students of biology. In the death of Mr. Craven Iowa has lost a young man whose marked ability, energy and purpose, gave promise of a useful scientific career.

JOHN L. TILTON.

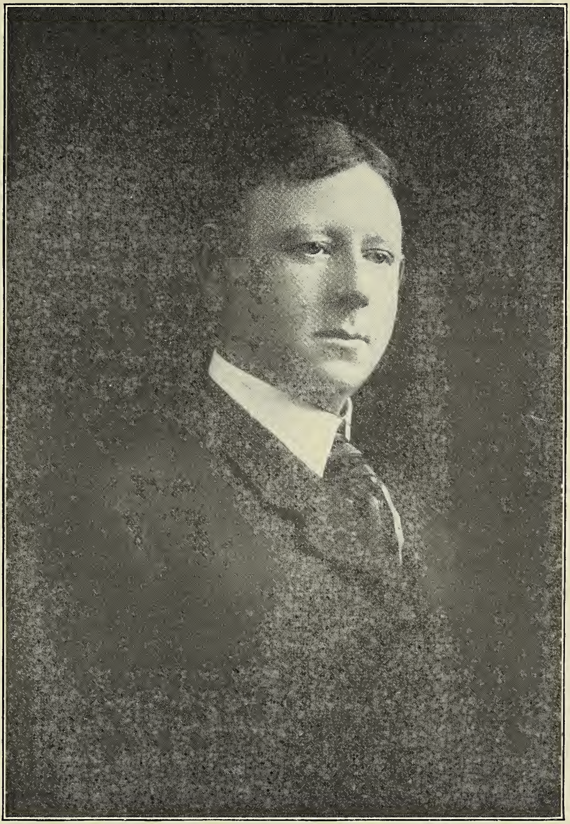
DR. WILBERT EUGENE HARRIMAN.

In 1896 Dr. Harriman became a fellow of the Iowa Academy of Science of which he has been a faithful member, though he never presented any papers, nor was it his privilege to attend many of the meetings because of his professional work. However, he was deeply interested in scientific subjects, especially those connected in any way with the progress of medical science. He was born in Cherokee, Iowa, on December 4, 1871, and died in Hampton, Iowa, March 17, 1909. On his father's side he came from a long line of New England ancestry, and on his mother's side of Scotch and German ancestry. He graduated from the Hampton High School in June, 1890, entering Iowa State College July, 1890, from which he was graduated with the degree of B. S. in November, 1893. He finished one year's work in the medical department of the University of Iowa, where he won a prize in a competitive examination in histology. He studied medicine in the office of Dr. W. A. Rohlf, of Hampton, during the long winter vacations. He passed the medical examination of the State Board ana located in Gilbert, Story county. In 1894 he entered Jefferson Medical College, graduating in 1895. He also pursued work in the medical department of the University of Pennsylvania and later in the Post-graduate Medical College in Chicago.

He was elected college physician and professor of histology, pathology and physiology, locating in Ames in 1895. To the great regret of the entire college community, he resigned his position as college physician on September 1, 1907, because of ill health, the board reluctantly accepting his resignation.

He was a member of the State Medical Association and Fellow in the American Academy of Medicine, and the Iowa Academy of Science. Papers prepared with care and skill were presented to some of the meetings of the Medical Associations. He was esteemed and reported by his fellow practitioners as a worthy and able professional man.

Dr. Harriman was a splendid type of citizen and the community irrespective of creed or party felt the loss to an unusual degree. In the class room he was concise, and no student ever left the room without feeling that some difficult point had been made clear by his elucidation. The writer has many times heard words of praise spoken of his work as a lecturer and an expounder of the intricate problems of physiology and medicine. Dr. Harriman will, however, be best known for service to the community and the college in particular as a physician and surgeon. During the epidemic of typhoid fever in 1900 he showed his unusual ability to cope with existing conditions and to place sanitary conditions on a better basis. He worked night and day and earned the everlasting gratitude of a large body of students and the faculty. It was my pleasure to have been associated with him in tracing the cause of this typhoid epidemic. He spared neither time nor effort to correct the conditions and



Dr. Harriman.

suggest changes essential for the health of the student body. It was at his suggestion, a few years later, that a systematic study was made of the water and milk supply of the college. He was ever urgent for a sewage disposal system and good water supply.

In this day of specialization the "family doctor" is almost a thing of the past, but the doctor was not only true to his calling as a surgeon but a good "Family Doctor." He knew all about the members of the family and what they needed to restore them to health. It was not always medicine they needed. The patient felt that he was safe in his hands. That he had the confidence is shown in tne fact that his office was always filled with patients waiting for him. To all it was the same kind word and treatment. No matter what time of the day he was ready to serve his fellow men. It can be truly said that he offered his own life for the good of others.

So conscientious was he in his work that when a patient had a serious sickness he never left him until he was certain that the patient was on the road to recovery. No matter in what circumstances the patient was, he received the same treatment. This he considered to be the duty of a physician.

It was his great interest in the student that commended him to every one in this community. There were stated hours in which the students could see the doctor, at the College Hospital, but they came to his office and called on him at all hours of the day and night. He was always ready to help them and in this way avoided many serious troubles.

His sensitive nature and conscientious scruples made him more than careful in his medical work. His diagnosis was carefully made and consequently few errors in treatment. I had many talks with him, and he frequently unbosomed himself in his frank and straightforward way about many subjects we had in common. He had a profound reverence for authority and felt deeply chagrined when an injustice was done to some one. It was in this frank and straightforward way that he won the esteem and respect of his fellow men. I love to think of the good doctor as I saw him in his professional work in his prime, and when he was a student in my classes in the early nineties. His work as a student was an inspiration to me and his fellow students.

The last time I saw him his health had been undermined to such an extent that he said, "I will have to quit practice for a while," but his message to me was cheering and full of hope. It was the same kindly greeting as in earlier days. I did not think it would be a parting message, but such it proved to be. We looked back over the years when he told me that he was anxious to practice medicine in Ames and establish his name among good practitioners of the State and become a worthy member of our community.

Though young in years the service he did to his fellow men was rich in blessings and full of fruition. His life was one of strict service to others. What more can be said of any man devoted to his work of helping humanity? It is blessed beyond measure and our words are inadequate to express our gratitude to the man who led an unostentatious life for the good of mankind.

L. H. Pammel,
A. C. Page,
G. F. Kay.

PRESIDENT'S ADDRESS.

THE WORK OF THE IOWA GEOLOGICAL SURVEY.

BY SAMUEL CALVIN.

The present Geological Survey was organized in 1892. Before that time Iowa had had the honor and the distinction of being served in the office of State Geologist by that Nestor of American Geology and Paleontology, James Hall, and by his worthy successor, Dr. Charles A. White. It was Iowa's great misfortune that neither of these distinguished geologists was permitted to do more than the merest reconnoissance work. Official geological work in Iowa may indeed claim three distinguished names, for geological investigation began in this state under the direction of David Dale Owen, United States Geoolgist, in the autumn of 1839. Considering the limitations under which the earlier geologists labored, the extent and accuracy of their observations are matters of constant surprise to their successors.

All that was done, however, and all that could be done by the earlier geologists, was to determine in a general way the age and characteristics of the geological formations which occurred within the state, and something of their surface distribution. Nothing like detailed work was possible. There was neither time nor opportunity to ascertain the limits of the minor divisions of the formations, nor could the zonal distribution of faunas be worked out; the geological resources of the state could be but dimly appreciated; approximation only could be made to the boundary lines of the formational areas.

The first great aim of the present Geological Survey was to make maps showing as accurately as conditions would permit the exact areas in which the several formations are exposed at the surface. In a country which, like Iowa, is deeply covered with glacial drift, the work of geological mapping is one of extreme difficulty. Even now, over large areas, it is impossible to do more than to draw lines where the few scattered outcrops indicate the boundaries should be found if the drift mantle were removed. The work has been pursued with the purpose of getting the nearest possible approximation to accuracy. The surface has been studied county by county, and the first studies were so distributed as to cover areas of strategic importance, areas in which contact lines, special formational characteristics, or geological products of commercial value were expected to occur. In the matter of the determination of formational boundaries the results have been such as to make it possible to publish the large-scale geological map which was issued as part of Professor Wilder's Report for 1905. A comparison of this with the geological maps of Iowa previously published will show what has been done in the direction of detailed mapping of Iowa's geological formations. For seventy-five of the ninety-nine counties of the state geological maps have been published on a scale of half an inch to the mile, and the geological structure of these counties has been set out in detailed reports. County reports embrace all the information which may be collected by careful study of topography, drainage, building materials and other quarry products, clays, useful minerals, soils, sands and gravels which may be used in the improvement of roads or for other purposes, water supplies, possible water powers, and whatever else it may be of service for the people to know with respect to their natural resources.

As a contribution to knowledge of great importance to the people of Iowa there was published, early in the history of the present Survey, a preliminary report on coal by Keyes. In this volume was assembled all the information relating to Iowa coals available at the date of publication. Special reports on the coal counties have since given greater precision to our knowledge of the subject; and the Survey has ready for the press a monograph on Iowa Coal which will place before the people all the facts which have been accumulating during the past ten or twelve years. The work on the coal monograph was begun by Professor Wilder while he occupied the position of State Geologist; his interest and efforts have been continued since large business affairs called him from the state; under his direction the field work and preparation of the manuscript for the volume has been carried forward by Henry Hinds and Assistant State Geologist Lees. The investigation of the peat deposits of the state and their possible use as a source of fuel supply has been completed under the direction of Dr. S. W. Beyer, and the manuscript is ready for the printer.

To Dr. Beyer the Survey and the people of Iowa are indebted for exhaustive and masterly reports on Clays and Clay Products, and on Quarry Products. These subjects are treated in volumes XIV and XVII of the Iowa Geological Reports. The work set out in these volumes has won recognition and high commendation from experts everywhere. As noted above, the report on peat, by Dr. Beyer, is ready for publication; and in the course of another year or two the same investigator will set before the people detailed information relative to roads and road material.

The investigation of the resources of Iowa in the matter of underground waters suitable for municipal, domestic and medicinal uses has been in the hands of Professor Wm. H. Norton ever since the Survey was established. A preliminary report of great economic and scientific value was issued as part of volume VI, in the year 1897. The collection and classification of data have been continued without interruption since that report on water resources was published. The amount of material in hand is large and it is of the greatest importance. The Survey contemplates the early publication of a volume which will place before the people of the state full and trustworthy information on a subject of the utmost importance to their welfare.

The gypsum deposits of Iowa have Fort Dodge as their center. Though limited to a small area, which probably does not exceed fifty square miles, these deposits have become the basis of a manufacturing industry of large proportions. The geology of the region was studied by Keyes, and later, in more minute detail, by Wilder. In his report on the geology of Webster county Wilder presents the results of very exhaustive investigation on the areal extent, the thickness and the availability of the deposits as well as on the methods of mining, quarrying and manufacturing. He suggests additional uses for gypsum products and points out possible improvements in the methods of manufacture. The results of personal studies relating to the manufacture and uses of gypsum in France and Germany are incorporated in an Appendix to the Webster county report, and so there is placed before the manufacturers of

Iowa, in reliable form, a fund of useful information that should prove of the highest value in the further development of this important industry.

The lead and zinc resources of the state have received deserved attention. Early in the history of the present Survey a full report on the mining industry around Dubuque was prepared by Leonard on the basis of extended investigations made in the field, and was published in volume VI. Later, the subject was reinvestigated, and in greater detail, by Bain, and the results of this later work constitute the greater and the more important part of the report on the Geology of Dubuque county, which appears in volume X.

The oldest of the rock formations native to Iowa, and the only deposit of pre-Cambrian age in the state, is the Sioux quartzite. This is limited to a small area in the extreme northwest corner of Lyon county, but it is quite extensively developed northward and westward in Minnesota and South Dakota. This unique formation was deemed worthy of a special report, which, after careful field study, was prepared by Dr. Beyer.

In spite of all that can be said and done, there are people in enlightened Iowa who persist in the erroneous notion that it is necessary only to bore deep enough to get supplies of petroleum and natural gas in any desired quantities in any locality. Many thousands of dollars have been uselessly expended in the search for these products in regions that had previously been explored with the drill in efforts to get supplies of water. The records of these drill holes were available, but the parties interested seem to have been possessed, or obsessed, by the curious notion that wells drilled through the geological formations to get water prove nothing as to the presence of gas or oil. When you want water, drill for water; and when you want gas or oil, drill for gas or oil; as if the intent of the driller exercised some mysterious influence on the nature of the products to be obtained from the deeper-lying strata. The Survey has told the people the truth in all such cases and has conscientiously tried to get them to see it, but the truth has proved in most instances to be exceedingly unwelcome. Some have tried to ward off the unwelcome facts and compel the rocks of Iowa to yield products they do not possess by indulging in coarse abuse of the Survey and its officers, but the result has not been a pronounced success. The position of the Survey has been sustained in every case; it has nothing to apologize for, nothing to recant; it may be worthy of note, though in no way unexpected, that the loudest and coarsest of the vilifiers have never offered a single word of manly apology. The small amounts of gas from deposits of sand and gravel in the drift have been recognized since before the Survey began, and it is hoped that many more of these reservoirs may be found. Letts and Herndon are the best known localities among those where Pleistocene gas is known to exist. The deep wells, so widely distributed, have in general settled the question of oil or gas from the older geological horizons, but there yet remain a few unexplored areas that may some time surprise us by becoming productive.

The work of the Survey is now far enough advanced to make it possible to construct a detailed section of the rocks of Iowa, fairly correct. Thin zones of economic or scientific importance have been determined and recognized, in some instances over hundred of square miles. For example, the non-magnesian, lithographic limestone which is the principal basis of the Portland cement industry at Mason City, has been traced from Iowa City to Howard and Mitchell counties and across the line into Minnesota. A reef of stromatoporoid corals, intimately related stratigraphically to the lithographic beds, and of no small economic importance, has a geographic distribution equally extensive. Other well defined zones of the Devonian system are easily recognizable. To Norton we are indebted for the recognition and definition of the lower members of the Devonian, the Otis and the Coggan beds, which, however, are found only in the southern part of the Devonian area. Similar zones, definite and constant as to position and having great geological significance, have been determined for the Niagaran limestones, for the various members of the Ordovician, for all of our geologic systems ranging from the Cambrian to the Upper Createaceous.

The Iowa Geological Survey may be credited with some of the most important contributions yet made to our knowledge of Pleistocene geology. Before the Survey came into existence Chamberlin, Salisbury and McGee, by a series of masterly investigations, had determined the criteria which might be used in the differentiation of successive drift sheets and had pointed the way to the correct solution of Pleistocene problems. Three episodes of glaciation were recognized in a general way, and had been named by Chamberlin the Kansan, Iowan and Wisconsin, but the limits of these were only vaguely known. Bain, at that time Assistant State Geologist, demonstrated that the gravel beds at Afton Junction lay beneath the Kansan of Chamberlin, and that, below the gravels, there was an older drift sheet whose true geological position had been misunderstood. In this way a fourth glacial deposit took its true place in the Pleistocene series. This, although the fourth in the order of recognition, was in reality, so far as now known, the first in the order of time. It has not yet received its proper distinguishing geographic name, but is simply known as the pre-Kansan or sub-Aftonian. It has been exposed by the erosion of the stream in the valley of the Grand river a mile or two below Afton Junction, in the valley of the Little Sioux in the northern part of Harrison county, at the base of the Missouri river bluffs in Fremont and Mills counties and at other points in the southwestern part of the state; while eastward it shows in the Mississippi bluffs and lateral ravines near Muscatine. It has been seen in artificial excavations as in the great Oelwein cut in Fayette county; it is known to occur in many well sections; but there is no locality at present known where it is found as the surface drift. At all its exposures we see only the edge of the deposit, everywhere it is overlain by younger formations. We are indebted to Leverett for the last of the drift sheets to be recognized, the Illinoian. This, the fifth in order of recognition, is the third in order of chronological sucession. The Iowa Survey has worked out the margins of the several drift sheets, so far as the margins fall within the borders of the state; it has studied and described the differential structural characters of the deposits; it has noted and recorded the relative amounts of erosion, weathering and general alteration in the surface of the Kansan, Illinoian, Iowan and Wisconsin respectively, and, with proper caution, has used these as indices of the relative age of the formations; it has studied the interglacial deposits and has drawn conclusions concerning the interglacial faunas, floras and climates. The soils of Iowa constitute her most valuable geological endowment; over extended areas the fertility and adaptability of the soil varies with the nature of the underlying drift; there are alluvial soils, lacustrine soils, loess soils as well as soils of glacial origin; studies of the Pleistocene deposits are, in the highest sense, contributions to Economic Geology.

Apart from the sheets of glacial drift, which constitute the most important of the Pleistocene deposits, whether viewed from the economic or the purely scientific side, the Survey has demonstrated the stratigraphic position and areal extent of interglacial and postglacial sands and gravels that may not be neglected. These are important not only as furnishing sands for use in building, and gravels for the improvement of roads, but with the multitudinous uses of cement in modern construction they attain an economic value not easily calculated. There are at least three well defined sand and gravel horizons in the Pleistocene; two are interglacial, one postglacial. Between the pre-Kansan and the Kansan drifts are extensive beds known as Aftonian, which, as recent work has demonstrated, are very extensively developed throughout southern, southwestern and western Iowa. Studies by Shimek during the last field season have broadened our knowledge of the extent and distribution of these Aftonian beds, and when we remember that they occur in regions where there are few stone quarries and the modern streams flow through mud flats, without sand bars, the economic importance of the Aftonian sands and gravels may be appreciated.

Great, however, as is their economic value, the purely scientific significance of the Aftonian beds is even greater. The Aftonian gravels, especially up and down the western slope, have been yielding remains of animals that flourished during the interglacial interval, while peat and soil beds of the same age are telling us of the forests and humbler plants that furnished shelter and food for the Aftonian fauna. The results of these Aftonian studies have not yet been published, but we are prepared to say that during Aftonian time Iowa supported three great elephants, *Elephas imperator*, *Elephas columbi* and *E. primigenius*, one mastodon, *Mammut americanum*, at least one large camel, a large stag intermediate between the moose and the elk, and at least two species of horses. In addition to the bones and teeth of these great mammals the Aftonian sands have furnished shells of river mollusks, identical, according to Shimek, with the species living in our modern streams. The Aftonian climate was not very different from that experienced by modern Iowa. The important and significant result of these discoveries in western Iowa lies in the fact that for the first time, the exact horizons of the *Equus* and *Elephas imperator* beds has been definitely fixed. These same great mammals have been found in Pleistocene deposits in western Nebraska, in Texas, in Oklahoma, and in other regions which were not covered with glacial drift; but the precise position of the beds, stratigraphically, could not be determined. The work in Iowa gives us an undoubted, definite horizon. The studies in Iowa further demonstrate that the Aftonian was a real interglacial interval, that its deposits do not represent a mere "fluctuation and temporary local withdrawal of the pre-Kansan ice" as some with meager and partial knowledge of the subject are disposed to insist. The Aftonian, as we now see it, was a time when extensive grassy plains alternated with luxuriant forests, a time when soils were developed, when great peat beds accumulated, when heavy rains fell and swollen rivers frequently overflowed their flood plains, when this latitude had a climate which permitted the modern types of mollusks to occupy the streams and when great herbivores found an abundance of food on the open plains, in the warmer river valleys, or over the thinly wooded slopes.

There is another interglacial interval between the Kansan and the Illinoian stages of ice invasion, the records of which have been determined by Leverett of the United States Geological Survey. Near Yarmouth in Des Moines county, soil and peat belonging to this horizon are well developed, and these have furnished remains of at least two types belonging to the recent fauna, the wood rabbit and the skunk. Between the Aftonian and the Yarmouth changes in the life of the continent had taken place, but our knowledge of the Yarmouth deposits and the fossil mammals they contain is as yet too meager to enable us to say how great the changes were.

Extensive beds of gravel, probably representing the beginning of the Yarmouth interval, were deposited by floods at the time the Kansan ice was melting. These have been called the Buchanan gravels. They attain their best development in the northeastern counties of the state, but they are known as far south as Iowa City, and they have furnished enormous quantities of railway ballast near Leroy in Minnesota. For railway ballast, for the improvement of village streets and country roads, for all grades and phases of cement construction, for ordinary building sands, the Buchanan gravels so generally distributed in Delaware, Buchanan and other northeastern counties as to be conveniently available in almost every neighborhood, furnish ideal materials practically inexhaustible. For reasons easily understood and fully set out in some of the reports the Buchanan gravels occur on the uplands as well as in what were sags and valleys in the ice moulded surface of the Kansan drift, and it is to this fact that we owe their presence in almost every neighborhood, no matter where located.

There are some beds of rather fine, stratified sand distributed along the stream valleys which originate in the Iowan plain, referable to the relatively meager floods which resulted from the melting of the Iowan ice. The deposits are unimportant commercially, but they help to illuminate and unify the complex history of the Pleistocene period, and every phase of this history is of the utmost importance to the inhabitants of Iowa.

As the work of the Survey has conclusively demonstrated, the gravels deposited in connection with the melting of the Wisconsin ice, at the very dawn of postglacial time, are by far the most extensive of all the Pleistocene deposits of similar character and origin. In the north-central counties of the state great sheets of gravel cover areas equal to entire townships, while gravel kames and eskers are distributed as conspicuous knobs and ridges over much of the surface embraced in the Wisconsin area. These gravel ridges culminate in Ocheyedan Mound in Osceola county, a great kame rising 100 feet above the surrounding prairie, keeping watch over a radius of twenty-five miles or more, its summit well worthy of the distinction which it reputedly holds of being the highest point of land in Iowa. For detailed studies of the Wisconsin drift, of the associated sheets and ridges of gravel, and of the characteristics and geographic position of the Altamont moraine on the western side of the Wisconsin lobe, the Survey is indebted to the painstaking work of Professor Macbride.

Iowa is rich in its possessions of another Pleistocene deposit of incalculable economic importance, the Loess. No subject has been more misunderstood, no subject has given rise to more uselss and meaningless controversy, no subject has been responsible for more grotesque and untenable hypotheses as to its origin and original distribution, than the Loess. Iowa offers unsurpassed opportunities for the study of this remarkable geological deposit, and an Iowan who has given some time in recent years to Survey work, but who had critically studied thousands of loess sections years before the Survey was organized, has marshalled the arguments and the facts in favor of the eolian origin of loess so convincingly that his views are now generally accepted by leading geologists everywhere. Professor Shimek was attracted to the loess by his interest in the life, habits and distribution of land snails which he had studied more patiently and exhaustively than probably any other living naturalist. The loess is very generally fossiliferous, and practically all of its fossils are shells of terristrial mollusks. These fossils bear conclusive evidence of having been buried where the creatures lived and died. Professor Shimek has driven home the argument that no theory of loess origin is tenable that does not satisfactorily account for the presence and distribution of its fossil land snails. The loess fossils throw light on the humidity and temperature of the atmosphere and on the distribution of plants at the time the loess was forming. The loess and its fauna and all the economic, geologic, meteorologic and botanic problems connected with it will be the subject of a monograph, now in preparation by Shimek, which will soon appear as one of the volumes of the Iowa Geological Reports.

Among the more distinctive contributions made by the Survey to pure science attention may be called to the discovery of the great Devonian fish bed in the State Quarry limestone near North Liberty. The fishes from the State Quarry bed, together with other Devonian fishes from Iowa, have been studied by the scholarly master of this branch of Paleontology, Dr. Charles R. Eastman of Harvard, and his report has been recently published as volume XVIII of our current series. As shown by this report, the new fish bed has furnished a number of genera and species at present unknown elsewhere in the world. Some of these new forms illuminate in interesting ways the history of fish development and bring to our knowledge ancestral phases of certain groups which have long been known to students of science.

Among other contributions to pure science we may note that the Survey has brought order out of the apparently hopeless confusion which previously existed relative to the limits, distribution and characteristics of the Galena and so-called Trenton limestones; it has shown that no representatives of the lower Devonian occur in our geological column, only late Middle, and part of the Upper Devonian being present; it has proved the great overlap and unconformity in the northern part of the state whereby comparatively late Devonian has been brought to rest on eroded Ordovician, with the consequent apparent thinning and complete disappearance of the Niagara in that direction; the definite life zones of the various rock systems from Cambrian to Carboniferous have been worked out with a fair degree of thoroughness; the true correlation of the Iowa Cretaceous has been ascertained; and the characteristics, thickness and distribution of the earlier beds underneath younger formations have been studied and mapped in connection with Norton's work on deep wells.

Precise and definite knowledge of every sort and kind has a value that it is difficult to express in the standard units making up the currency of commerce. It has been the aim of the Survey to collect and furnish trustworthy information, the fullest possible, relative to the geologic structure and geologic resources of Iowa; but while the purely economic side of the subject has necessarily been emphasized more or less in all the work so far done, any facts that could make knowledge clearer, broader, more definite, have not been neglected.

Facts that seem at first to be in no way related to commercial or industrial activities, may be the germs from which will spring some great body of knowledge of the utmost importance to the well being of mankind. The oft quoted example of the twitching of the muscles in the legs of a frog under an electrical stimulus seemed as far removed as possible from anything that might contribute to the accumulation of wealth or the promotion of human comfort, and yet that simple fact was the starting point from which have developed the marvelous uses and applications of electricity which are of such stupendous and daily growing importance in modern human life. The pure science of today becomes the basis of the applied science of to-morrow, and enlightened states, the world over, realize that money expended for the prosecution and encouragement of scientific research, is money well invested. By the substitution of definite knowledge for vague uncertainty relative to water supplies, coal, lead and zinc ores, oil, gas, Portland cement materials, clays and all other natural products, the Survey has saved to the citizens of Iowa, many times over, all that the Survey has cost.

As an aid to public education, helping the people to see and appreciate and correctly interpret the geological phenomena which lie all about them, helping them to view the world in which they live understandingly, instead of looking at it with the vague, dull, comprehensionless mental attitude of the unlearned savage, the Iowa Geological Survey has earned its place as an important factor in contributing to the general intelligence of this most beautiful, most prosperous, most intelligent state.

THE POLYPORACEAE OF FAYETTE, IOWA.

BY GUY WEST WILSON.

The *Polyporaceae* are a group of most interesting fungi which have of recent years assumed a position of prime economic importance as it has been demonstrated that many of them cause the decay of timber trees which formerly they were supposed to follow. The parasitic nature of these fungi has added a new incentive to their careful study. Some species are found only on the diseased portion of living trees, while others appear to inhabit only dead timber. Of these it is not improbable that a considerable number may be able to infect living timber and later to maintain themselves on the wood as long as those portions remain which furnish them with their food.

The present paper embodies the field observations upon species of this family in the vicinity of Fayette. Whilst the list can lay no claim to be other than a preliminary paper, several species are recorded as parasites which are not so indicated by Dr. Murrill in his monograph of the family,* while others are of interest because of the extension of their range. The majority of the species have been sent to Dr. Murrill for verification. The nomenclature of his monograph, which is the only comprehensive treatment of the American species, has been followed and such synonyms added as were necessary to correlate the list with other publications on Iowa *Polyporaceae.*

1. HYDNOPORIA FUSCESCENS (Schw.) Murrill. (*Irpex cinnamomeus* Fries.)

This species, which at maturity has the appearance of a resupinate *Hydnum*, is very common on various oaks. If the tree is still upright the entire surface may be covered; but on fallen branches only the lower portion is affected, giving quite a varied appearance to the fungus.

2. FOMITIPORIA OBLIQUIFORMIS Murrill.

The present species was described from material collected on hard wood logs near Cincinnati, Ohio, and is also recorded from Pennsylvania. In our territory it occurs both as a parasite and a saprophyte. It has been collected several times from wounds on oak and Mr. Learn has found it on *Populus grandidentata* in the northern portion of the county.

3. IRPICIPORUS LACTEUS (Fries) Murrill. (*Irpex Tulipiferae* (Schw.) Fries.)

Common on dead and living wood of various species. While usually considered a saprophyte this species is a true parasite on various species of wild and cultivated *Prunaceae.* Several cherry orchards in the vicinity, and numerous examples of the wild cherry have been noted as having succumbed to the ravages of this species. One orchard in particular was noted which has been almost depleted by the present species in company with *Coriolus prolificans*

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*N. Am. Flora, Vol. pts. 1 and 2.

and *Hapalopilus gilvus*. The additional hosts noted locally are *Rhus glabra*, *Populus grandidentata* and various oaks.

4. Poronidulus conchifer (Schw.) Murrill. (*Polyporus conchifer* Schw., *Polystictus conchifer* Schw.)

Common on fallen twigs of the elm. (*Ulmus americana*).

5. Coriolus versicolor (L.) Quel. (*Polyporus versicolor* (L.) Fries), *Polystictus versicolor* (Fries.)

This beautiful species is common on almost all our forest trees and shrubs. It is one of our worst forest pests and often invades the orchard and ornamental plantations. It causes a serious disease of the lilac and affects the wild grape.

6. Coriolus nogromarginatus (Schw.) Murrill. (*Polyporus hirsutus* Fries, *Polystictus pergamiuus* Fries.)

Common and variable, on numerous species of dead wood.

7. Coriolus prolificans (Fries) Murrill. (*Polyporus pergamenus* Fries, *Polystictus pergaminus* Fries.)

Very common both as a parasite and saprophyte on *Quercus, Betula, Populus*, and less frequently on other trees.

8. Coriolellus sepium (Berk.) Murrill. (*Trametes sepium* Berk.)

Not common, on dead oak both in the forest and in structural work.

9. Tyromyces semipeliatus (Peck) Murrill. (*Polypurus semipeliatus* Peck.)

Rare on *Salix*, upon which it is a wound parasite, gaining entrance through dead branches.

10. Spongipellis unicolor (Schw.) Murrill. (*Polyporus obtusus* Berk.)

This handsome species is not uncommon on oak saplings throughout the county. It is a wound parasite.

11. Spongipellis occidentalis Murrill.

This species, originally described from specimens collected on beech (*Fagus*), has been previously reported only from New York. A fine specimen was found on a wound of a trunk of *Ulmus americana* in Fayette. The species is quite distinct from the preceding, which it resembles in being a wound parasite. The denser pelius, smaller pores, and the brittleness of the later upon drying easily separate it from the former species.

12. Bjerkandera adusta (Willd.) Karst. (*Polyporus adustus* Fries.)

A common and variable species which may be either a true parasite or a saprophyte. The light colored, imbricate pelius and smoke colored hymenium easily separate this species. I have found it on erect trunks grading into a pseudo resupinate form which at first would never be taken for this species. Common on oak, basswood, birch, etc.

13. Bjerkandera fumosa (Pers.) Karst. (*Polyporus fumusus* Fries).

Much larger and with a lighter colored hymenium than the preceding species. A single collection was made near Fayette on an old elm log.

14. Hexagonia alveolaris (DC.) Murrill. (*Favolus europeaeus* Fries).

Very common on fallen branches and dead twigs of various trees.

15. Polyporus arcularius (Batch) Fries.

Common on fallen twigs, buried roots, and stumps of deciduous trees. The species is quite variable, although easily recognized by the alveolar pores, ciliated margin and palid pelius, a combination of characters unique among the northern species of the genus.

16. *Polyporus fissus* Berk.

A very large and conspicuous species which has been collected but once in the vicinity of Fayette. The specimens were growing on a badly decayed log, probably elm.

17. Grieola frondosa (Dicks.) S. F. Gray. (*Polyporus frondosus* Fries).

A very beautiful species which has been collected once in humis at the base of an oak, near Fayette.

18. Pycnoporus cinnabarinus (Jacq.) Karst. (*Trametes cinnabarina* Fries, *Polystictus cinnabarinus* Fries).

A very conspicuous species easily recognized by its bright color. Fairly abundant on fallen wild cherry.

19. Laetiporus speciosus (Batt.) Murrill. (*Polyporus sulphureus* Fries, *P. cincinnatus* Morgan).

Quite common on various living and dead trees, especially oak, ash, and wild cherry. This is the only edible species of the family, at least in so far as local flora is concerned.

20. Funalia stuppea (Berk.) Murrill. (*Trametes Peckii* Klachb).

A very distinct species, easily recognized by its hirsute pileus and large very irregular pores. Not uncommon on poplar.

21. Hapalopilus gilvus (Schw.) Murrill. (*Polyporus gilvus* Schw).

A very common and rather constant species which is easily recognized by its firm sporophore which is of a yellowish or brownish tint. The individual sporophores are either scattered or imbricate and are produced in great abundance, much to the injury of our forests. The worst sufferer from its depridations is the oak. Various other trees are infected to a certain extent, among these being the cultivated cherry.

22. Ischnoderma fulginosus (Scop.) Murrill. (*Polyporus resinosus* Fries).

Common on dead wood, especially of the linden and red maple.

23. Fomes roseus (Alb. & Schw.) Cooke.

On structural pine, Clermont, (C. D. Learn.) The rose colored sporophore easily distinguishes this from our other species.

24. Fomes fraxineus (Bull.) Cooke.

Not common on *Fraxinus*. Collected at Clermont and Fayette by C. D. Learn.

25. Fomes ohiensis (Berk.) Murrill. (*Trametes ohiensis* Berk).

Rare on oak posts.

26. Fomes populinus (Schum.) Cooke.

This species does not appear to be very common as it has been collected only two or three times. It is parasitic on *Acer saccharinum* and *A. saccharum*.

27. Pyropolyporus ignarius (L.) Murrill. (*Fomes ignarius* Gill., *F. nigricans* Gill).

This is one of our commonest and most variable species of pasitic polypores. It causes no end of damage to certain of our forest trees. Two forms are recognizable; the first, or typical form, has the hymenium brown, the surface less rimose than in the second, and is more broadly shelving in habit; the other form being narrower and more nearly hoof-shaped, with a bluish hymenium. This is *Fomes nigricans*, which upon first acquaintance appears distinct enough to warrant its recognition as a distinct species. A collection made by

Mr. Learn near Clermont makes this treatment of the forms impossible as the habit is that of *F. nigricans;* but with the brown hymenium of the typical form. At most these can be ranked only as varieties. The typical form is a wound parasite on *Juglans cinerea* and *Ostrya virginica,* while the other form is confined to *Populus.*

28. Pyropoluporus fulvus (Scop.) Murrill. (*Fomes fulvus* Gill).

Very common on the wild plum, destroying entire thickets, and sparingly on cultivated plums of American and European varieties.

29. Pyropolyporus Everhartii (Ellis & Gall.) Burrill. (*Mucorniporus Everhartii* Ellis & Gall., *Fomes rimosus* and *F. ignarius* Aut. p. p.)

This is a very common parasitic species, often reaching a large size. It is parasitic on various species of *Quercus.*

30. Pyropolyporus conchatus (Pors.) Murrill.

Very common about Fayette. This is a very variable species, either peliate or resupinate, and in peliate forms often moss covered. The velvety fawn or light brown margin is quite characteristic. Very common as a parasite on *Crategus,* wild grape, ash, and as a saprophyte upon various species of deciduous wood.

31. Elfvingia fomentaria (L.) Murrill. (*Fomes fomentarius* Gill).

A specimen from *Betula papyrifera* is in the collection of Upper Iowa University.

32. Elfvingia lobata (Schw.) Murrill. (*Fomes reniformis* Morgan).

Not rare on dead deciduous wood. This species is an annual, the pelei becoming imbricate. It is easily distinguished from the following by this character and its smaller size.

33. Elfvingia megaloma (Lev.) Murrill. (*Fomes applanatus* of American authors).

Very common both as a parasitic and saprophyte on various deciduous trees.

34. Cerrena unicolor (Bull.) Murrill. (*Daedalea unicolor* Fries).

A very common saprophyte on various species of deciduous wood. It is easily mistaken for a *Coriolus* from which it differs in the daedaleoid pores.

35. Daedalea confragosa (Bolt.) Pers.

Very common both as a parasite and saprophyte on *Salix* and *Crategus.*

36. Lenzites betulins (L.) Fries.

Very common on oak and rare on birch.

37. Lenzites odora "Aut."

A poorly understood species of uncertain affinities. Common on railroad ties and structural timber.

38. Gleophyllum trabeum (Pers.) Murrill.

Common on fallen timber.

SOME PARASITIC POLYPORACEAE.

BY CLARENCE D. LEARN.

Up to within the past eight or ten years, very little attention had been paid in America to the study of those forms of fungi causing forest diseases. The reasons are obvious. Previously, the occurrence of a few diseased trees was practically unnoticed, due to the vast area of our forests. But, with the advance of the lumberman in the last decade, the situation has changed, and a demand has arisen among all classes of people for a more economical and rational treatment of the existing forest lands. The diseased trees of the primeval forest were ignored, as they were so few in comparison with the sound ones. While now the marked appreciation in the value of timber, cause the timber destroying agencies to become of immediate interest. These silent enemies of the forest are working here and there, not attracting the attention of the casual observer as do the careless habits of the lumberman and the forest fires.

The polypores were formerly supposed not to be of a parasitic nature, and the papers published upon them dealt only with the fruiting portion. While now their parasitic nature is established. The effect brought about through the growth of the fungus, is the important economic question which is considered in the present paper.

The field for work on forest diseases is a large one, and its possibilities are just becoming apparent. Compared with other fields of activity, there are but a few workers, among the more prominent of whom we might name Drs. von Schrenk, Spaulding, Metcalf, Hedgecock, and Professor Atkinson. The government is just beginning to take cognizance of these fungi as producing diseases of forest, nut, and shade trees as is shown by Orton and Ames in Plant Diseases in 1907, where mention of them is made forty-eight times.

In the present paper, I shall present a study of some of the higher fungi of the family Polyporaceæ, and describe the characteristic changes which their mycelia induce in the wood of the trees in which they grow. These fungi were observed in the field causing the decay ascribed to them.

The relation of the fungus to its host is a definite one. The question of the spore gaining its entrance is somewhat problematic. That any here studied gained entrance unaided, I believe is not safe to assert. Few of the fungi can gain an entrance unaided through the living layer of cambium tissue, which envelopes the entire tree, and while uninjured, serves as an effectual barrier against many of these enemies. For their entrance, fungi are usually dependent upon some agencies, usually gaining entrance through mechanical injuries to the host. There must be some condition conducive to infection, either a broken branch, a wound, or lack of vitality. When a tree once becomes diseased, the mycelial threads spread rapidly, filling the heart wood with holes or changing it to a brittle substance having none of the properties of wood. These changes weaken the trunk, and now it is only a question of time until the tree is broken by the wind.

That some fungi possess great adaptability is shown by Elfvingia megaloma, which attacks both living and dead trees, as well as stumps and logs, showing it to be both parasitic and saprophytic. Pyropolyporus conchatus also has this dual nature. The greater majority of parasitic diseases, however, is induced by a wound. As stated before, in most instances there must be some means for the spore to gain access other than directly through the cambium layer. Hence if it be true that injury is necessary for infection, we might decrease the possibility of attack by care in handling trees to be transplanted, in pruning, and also in protection. The true parasite is not to be found among the specimens under consideration in this paper. Very few wood rotting fungi are capable of entering an uninjured tree. Nearly all gain lodgement in wounds, grow in from these, and rot the wood.

The effect of parasite on the host may remain unnoticed for some time, as the growth is very slow. The first noticeable indication of the presence of a fungus disease is the sporophore. As the age of the fungus increases the greater is the number of sporophores, of which I have seen as many as twenty-five on a single host. When this stage is reached, the effect may be noticed in the dead branches at the top, and pale color of foliage. When the host becomes thus infected it succumbs to the wind by either being broken off or up-rooted.

A microscopic examination of some of these diseases shows that the wood tissues are penetrated by tiny mycelial threads. These threads are seen to attach themselves to the cell walls, and to pierce it in all directions. Thus these tiny threads form a network in the wood, and as they increase in number, they dissolve the walls of the wood cells converting them into food for their own consumption. In some cases it is the woody cell wall alone that is attacked; in other cases they consume the starch found in the cells; but in all cases of decay we find these mycelial threads are responsible for the mischief. These fine threads are the vegetative body of the fungus, the little shelf its fruiting body, on which it produces myriads of tiny spores.

The economic side of the problem is also worthy of our consideration. We find that there are but a very few kind of trees, if any at all, that are not subject to fungus diseases; and that both dead and living trees are attacked. A tree does not lie on the ground any time until it is nearly covered with fungus growth. If one is to realize any value from diseased trees they must be used before they reach the last stage, or before they fall. Some of these diseases affect the heart wood, rendering it useless for lumber, and of little value as fuel. That this problem is of the greatest importance is evidenced by the attitude of the government in studying its character, and trying to determine some means of prevention.

The species discussed in this paper are the most characteristic and common of this region, infesting our chief forest trees. They are *Pyropolyporus igniarius* (L.) Murrill; *Pyropolyporus Everhartii* (Ellii & Gall.) Murrill; *Pyropolyporus fulvus* (Scop.) Murrill; and *Elfvingia megaloma* (Lev.) Murrill.

Pyropolyporus igniarius: The sporophores of this fungus are among the commonest and best known of the largest fungi. The hoof-like shelves of this fungus occur widely distributed throughout the United States on the apple, oak, alder, beech, birch, maple and other species of broad leaved trees. In Plant

Diseases of 1907 by Orton and Ames, it is reported from eight different states from Maine to Montana. The fruit bodies are somewhat hoof-shaped, very hard, the upper surface black, while the fruiting surface is cinnamon brown. They are 4—8 inches long, 2—4 inches broad, ½—5 inches thick, and always occur singly. The hymenium is made up of rounded pores. The upper surface is marked by concentric furrows and ridges which mark off the annual layers. Thus the fungus is perennial.

The location of the sporophore on its host leads us to the question of the conditions favoring the entrance of the fungus. Since the mycelium cannot enter through the living cambium layer of the tree, some means of infection must be provided. These infection areas are provided in a variety of ways. From the location of the sporophore on the poplar at the knot-holes, we conclude that it gains entrance through the dying away of the lower limbs, and nature failing to heal the wound formed. The sporophores found upon butter-nut, iron-wood, and the apple were each located at a wound. Hence we conclude that the fungus must be a wound parasite. The microscopic spores found lodgement in the wounded area, and when proper moisture was obtained it germinated, sending its hyphæ into the heart wood. After it had received the proper nourishment, a sporophore was formed, and spores produced. The number of sporophores on a host varies from one to twenty-five.

Cross sections of a poplar tree present a very characteristic marking of the wood due to the different stages of decay and the coloration of the wood. The more advanced stages of decay lie at the center, the less advanced at the outer edge. It changes the heart wood to a light yellow color, and a very dark line separates it from the outer area which is a dark brown color from the knot-holes to the center there is the same condition, showing its entrance. Atkinson (3) stated, "that the peculiar discoloration of the wood accompanied the mycelium of this specie of fungus, and might be sufficient to identify the species even where no fruit forms of the fungus were present."

Pyropolyporus igniarius was found in greatest abundance infecting the poplar (Populus grandidentata), in fact, only one specimen was found on each of the apple and iron-wood, while several were found on the butter-nut. The fungus appeared to effect the black poplar more than it did the white; and it appeared to attack no trees less than five inches in diameter. In some groves of poplar the greater per cent of them were infected, while in others it was not so prominent.

The effects are easily to be seen in some localities where a greater number of the trees lie on the ground. From this we might conclude that it effects the tree as a whole, causing its decay and finally its fall. To estimate the possible loss is a difficult task; but as these trees are somewhat limited in quantity in localities we can readily see that the damage is great. If the tree is not used before it falls, the wood is of but little value, and, as far as lumber purposes is concerned it is of no value whatever. This fungus is not so serious as a hard wood disease, for it effects only our less important forest trees.

Poropolyporus Everhartii: This fungus is found to infest the broad leaved woods of this region, the hardiest and best of our timber, the red and white oak. We find this fungus is not as widely distributed over the United States as the former, and is only known on the oak and occasionally on the beech. In Plant Diseases of 1907 it is not reported.

The sporophores are hoof-shaped, very hard, the upper surface a very dark brown, while the fruiting surface is a cinnamon brown. They are 1½—12 inches long, 2—6 inches broad, by 1—6 inches thick and always occur singly. The hymenium is composed of rounded pores. The upper surface is marked by concentric ridges, which correspond to the annual growth. Thus the fungus is perennial, and attains to such an age that the upper surface may be covered with tiny moss plants, also deeply checked. If a sporophore is cut open, each year's growth is definitely marked by a lighter band separating them. This is quite distinct to about half its age, when the remainder is made up of lighter mycelial threads.

The condition favoring the entrance of the spores are through wounds, knot-holes, and cavities made by boring insects. It is from the location of the sporophore on the host, that we are led to determine the means of infection. There is also a greater diversity in the size of hosts of this fungus. It has been found frequently on red oaks of but three inches diameter; and not in connection with a wound or knot, and in most cases the host has been dead. But in the case of the larger trees it has never failed to be located at some wound or knot. In making a cross section of a tree containing one of these sporophores, I found a cavity which had been formed by some boring insect. The fungus being located at this cavity leads us to conclude that it either entered or grew out through this opening. In the light of the paper by Hopkins (8) on the relation of fungi and insect burrows, we must conclude that this species is a wound parasite. Due to these exposed areas the spore gained access through the cambium layer, and germinated, penetrating the heart wood of the tree. After the mycelium had penetrated the host gathering nourishment, a sporophore was formed, which is the only outward sign of disease. The location of these punks on the host varies. It is found on small trees near the ground, while on the larger trees it is observed higher up near a broken limb or wound. It is very seldom there is more than one specimen found on a tree.

A study of a cross section of an oak near one of these sporophores shows that the fungus has destroyed a definite portion of the entire heart wood, changing it to a light brown, pulpish mass. The light and dark wood is not separated by a darker area as in the former, but they are inter-mixed. One noticeable effect is that the medullary rays stand out very firm while the surrounding area is broken up.

The greater abundance of this fungus was found on the red oak, but it is not as common as the former studied. Still I have noticed that it is found but very little among the healthy timber, while among the dwarfed, scrubby jack oaks and the stunted burr-oaks of wind swept hillsides, it is more numerous. From this might we not conclude that the vitality of the tree gave a means of infection. The proportion of trees diseased to those not is very small, in fact much less than in Pyropolyporus igniarius.

The effect, economically, of this fungus is rather difficult to judge, as the extent of the disease is not very great. Although we find it scattered in different localities, yet there is no extensive tracts affected. But as its host is one of our most desirable kinds of woods, the result will be more noticeable later, if its spread is not checked. For each year a sporophore discharges myriads of spores, and some of these are sure of finding access in some tree, consequently the infected areas are increased each year. As no study has been made of a large diseased tree, we only form a conjecture as to its probable condition;

Plate I.—Fig. 1. Section of living red oak tree (Quercus rubra) near a sporophore **of** Pyropolyporus Everhartii, showing the decay; also the cavity formed by a **boring insect.**

Fig. 2. Section of the same tree, six feet above the sporophore, showing the presence of the mycelium also the cavity.

Plate II.—Fig. 1. Fruiting body of Pyropolyporus Everhartii showing the upper surface.

Fig. 2. Fruiting body of Pyropolyporus Everhartii showing the hymenial surface.

but from our knowledge of the effect on small trees, we may conclude that the lumber quality is destroyed, hence an economic loss, as it is being used very extensively for building purposes. For this reason this fungus is one of the most important economically of any of the species under consideration.

Pyropolyporus fulvus: This fungus affects only the diseased trunks of various species of Prunus and is widely distributed over North America and Europe. In Plant Diseases in 1907 it is not mentioned.

The fruiting bodies of this polypore vary in size from 1—6 inches long, ½—2 inches broad, by ¼—1½ inches thick. They form large masses when a large number are joined, as in some instances several limbs or main branches are covered with sporophores. The fruit bodies are elongated usually resupinate, very hard, edges nearly black, while the fruiting surface is a dark brown. This fungus does not grow in shelf form, but horizontal to the tree, leaving the concentric ridges only visible at the very edge of the sporophore; and frequently as resupinate forms coalescing in a series. The hymenium consists of regular pores of rounded minute openings. It is a perennial growth, hence tiny moss plants may be found growing upon it.

The condition favoring spore entrance is a wounded area. It has been observed that the sporophores are more common on the branches than on the trunk, and it has the appearance of working from the top downwards. Upon removing one of these sporophores no wounded area is visible, yet there are some located near a broken limb. Hence we conclude that it was through this broken limb that entrance was gained.

A cross section of a diseased branch shows that it is thoroughly infected, rendering it very brittle, while normally it is tough. Again the alternate area of light and dark wood prevails too near the sap wood. From these noticeable features it appears to attack only definite tissues or else follow the annual growth.

Its favorite host is the wild plum, and a few specimens have been observed on cultivated trees when pruned. One wild grove in particular where specimens were gathered, there was not a tree unaffected and most of them were dead. It appeared also that the cluster in the timber is much more subject to attack than those in the open, which might be explained by the former being more conducive to infection due to more moisture. Also the question arises if the fungus is strictly parasitic, for I believe specimens were gathered on dead hosts. If it be true that a plum supports this fungus long after its destruction, it is more tenacious of life than Pyropolyporus igniarius as the sporophore ceases to grow at the death of the host. Among the plums there is a greater proportion of diseased trees than any other yet studied.

The economic importance of this parasitic disease lies not in the fact of the commercial value of the wild plum, but in the tendency to infect the tame ones. Then it would have an economic importance for the fruit growers.

Elfvingia megaloma: The last fungus for consideration is Elfvingia megaloma, which is widely distributed over the United States and Canada. It is reported from Nebraska by Dr. Heald as parasitic upon cotton wood; likewise by D'Allemend from the same state under the name of *Fomes applanatus* parasitic upon cottonwood. As a parasite it attacks the red oaks in this region, but has not been found on the cottonwood; as a saprophyte it is found on dead trees, stumps and logs.

This fungus is of the bracket form with sporophores varying in size from 2—14 inches long, 1—8 inches wide, by ¾—2 inches thick; it is somewhat hoof-shaped or elongated, very hard, the upper surface dark colored and encrusted, while the fruiting surface is nearly white. The under surface is marked along the edge by an encrusted ridge, and the upper surface is marked by concentric ridges showing that it is perennial. In the popular mind it is associated with etching, because its hymenium changes to a darker color when bruised.

As a parasitic fungus on the red oak its sporophore is found near the ground. The means of infection is not very easily determined, as no wounds have been observed; but as the sporophores are located so near the ground we may conclude that infection is brought about through the roots, or at the base of the trunk near the ground line. This seems quite probable as sufficient moisture is one of the requisites for germination. The fact that it does not attack young trees, but becomes parasitic upon older trees in which the vitality has been lowered leads us to conclude that lack of vitality may be a means of infection. The mycelium spreads upward through the entire wood, and the trunk becomes thoroughly infested before the fungus attains sufficient vigor to produce its external fruiting bodies. The wood is rendered very brittle, and the tree is poorly fitted to withstand the force of wind in severe storms. The trees affected have always been large, probably more than thirty years old. The only evidence of the disease is the presence of a sporophore.

As a parasitic fungus this one is the least numerous of any yet studied. Only two specimens have been found on living trees. But as a saprophyte it is very common, being found on any dead tree, log or stump. But I believe that the log or stump of maple was more infected by it than any other. Dr. Heald (7) says, "Any logs or woods affected with this fungus should be burned as the fungus continues its growth. It seems quite probable that the vegetative mycelium is often the means of infection, rather than the spore direct."

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Plate III.—Fig. 1. Section of living plum tree (Prunus) showing the decay caused by Pyropolyporus fulvus and also the resupinate form of the fungus.

Fig. 2. Shelving forms of Pyropolyporus fulvus as found on a limb.

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THE UNDERGROUND ORGANS OF A FEW WEEDS.

BY L. H. PAMMEL AND ESTELLE D. FOGEL.

A study of some of the troublesome perennial weeds and their methods of extermination has led the authors to look up the botanical descriptions of the underground portions and manner of propagation.

Some writers have called all underground organs by which the plants in question propagate, rootstocks; others have cautiously said nothing about them and a few have called them roots and rootstock. It was this disagreement of authorities, in part, that made it seem desirable to make a more definite study to ascertain exactly how much of the underground portions are roots and how much are stems. This can be done only by a study of cross sections. Very little, so far as we know, has been published in English on the minute anatomy of the plants under discussion.

The plants in which we have been especially interested are Quack Grass, Canada Thistle, Horse Nettle, Wild Morning Glory, Bindweed, and Milkweed.

The present paper gives the result of our study after making stained mounts of all underground portions. Illustrations of the sections were made with the camera lucida and the photomicrograph.

Some Morphological Views.

The text-books on General Morphology consulted were Gray[1], Robinson and Fernald[2], Britton[3], and Van Tieghem[4]. The special papers and bulletins were Hitchcock and Clothier[5], Crozier[6], Dewey[7], Goff and Mayne[8], and Hitchcock[9].

Hitchcock and Clothier state that the European Morning Glory (*Convolvulus arvensis*) propagates by horizontal roots. The same authors also state that the Wild Morning Glory (*C. sepium*) propagates by slender underground stems. The section of Convolvulus in which *C. sepium* occurs, Calystegia, is characterized by Dr. Gray[10] as having creeping filiform rootstocks. The Milkweed, according to Hitchcock and Clothier, propagates by a creeping root on which adventitious buds appear, although Dewey states that the Milkweed and European Morning Glory propagate by rootstocks. Dewey[11] also states that the

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[8]First Principles of Agriculture. 107.
[9]The Subterranean Organs of Compositæ. Trans. Acad. Sci. St. Louis. *9*: 1, *1pl.*
[10]Syn. Fl. of N. A. 2:215.
[11]l.c. :14.

Horse Nettle is abundantly propagated by slender perennial rootstocks, while others state that it propagates by roots. With reference to the Canada Thistle, Vasey and Crozier[12], Goff and Mayne[13] and Dr. Gray state that the plant has creeping rootstocks which spread in every direction.

Besides one of the present authors[15], many other writers have accepted and made similar statements without giving the subject much attention.

Anatomical Structure.

Since the general characters will not always enable one to determine the nature of the underground organ, a microscopical study was made. In this way, we were able to determine definitely the extent of the root and stem.

The microscopic structure of roots and their origin is sufficiently indicated in many special treatises on this subject, especially by such writers as De Bary[16], Vesque[17], Marie[18], Jeffrey[19], Costantin[20] Gerard[21], Worsdell[22], Sargent[23], Van Tieghem[24], Strasburger, Noll, Schenck, and Karsten[25], Solreder[26], Holm[27], Andersson[28], Dodel[29], Goldsmith[30], and Van Tieghem[31].

Cirsium arvense (L.) Scop. Canada Thistle.

Root. The root is usually horizontal or occupies a vertical or oblique position in the soil, frequently strongly contorted; whitish or light brown with a strong odor; the small roots occur on the stem without definite order; when immersed in water a blackish extractive matter is removed. The thicker roots produce numerous adventitious buds along their course. The depth in the soil

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[12]l.c. :85.

[13]l.c. :109.

[14]Syn. Fl. of N. A. *1*:393.

[15]Pammel. Bull. Ia. Agr. Exp. Sta. 70 :324.

[16]Comparative Anatomy of the Vegetative Organs of the Phanerogams and Ferns. English Translation by Bower and Scott. Oxford. 1886.

[17]De'l Anatomie des tissus appliquee a la Classification des plants. Nouv. Arch. la Mus. d' Hist. Nat. II. *4*:1 ; *5*:291.

[18]Recherches sur la structure des Renonculacees. Ann. d. Sci. Nat. Bot. VI. *20*: 1-180. *8 pl.*

[19]Coulter and Chamberlain, Morphology of Angiosperms. 311. The Morphology of the Central Cylinder in the Angiosperms. Trans. Can. Inst. 40. *pl. 7-11.*

[20]Costantin. Etude comparee des tiges aeriennes et souterraines des Dicotyledones. Ann. Sci. Nat. Bot. VI. 16 :1-176. *pl. 1-8.*

[21]Recherches sur le passage de la Racine a la Tige. Ann. Sci. Nat. Bot. VI. *11*:279-430. *pl. 1-18.*

[22]A study of the Vascular System in certain orders of the Ranales. Ann. Bot. *22*: 651-628. *pl. 32, 33, 55f.*

[23]A Theory of the Origin of Monocotyledons founded on the Structure of their Seedlings. Ann. of Bot. *17* :1. *7 pl. 10 f.*

[24]Recherches sur la symetrie de structure des plantes vasculaires. Ann. Sci. Nat. V. *13* :185.

[25]A text-book of Botany. Eng. Trans., Lang. 128, 142, 154. 1908.

[26]Syst. Anat. d. Dicotyledonen, 1899.

[27]Am. Jour. Sci. *4*:298. (1897) ; *9*:355. (1908). *9*:355. (1900) 7:5. 1899.

[28]Ueber die Entwickelung der primaren Gefassbundelstrange der Monokotyledonen. Bot. Centrbl. *37* :586.

[29]Der Uebergang des Dicotyledonen Stangels in die Pfahl Wurzel-Pringsheim Jahrb. 8 :149-193. *pl 11-18.*

[30]Beitrage zur Entwickelungsgeschichte in Stengel und in der Hauptwuzel der Dicotyledonen—Dissertation. 1876.

[31]Traite de Botanique. 686, 750.

at which these buds occur varies from a few inches to more than two feet from the surface of the ground. It is not unusual for others among our common thistles to produce adventitious buds. This is indicated by Hitchcock and Clothier[32] for *Cirsium undulatum.* It is also true for *Cirsium canescens*[33] which spreads much like Canada Thistle. Dr. Bessey writes us that he observed this many years ago for this species.

The secondary structure is comparatively simple. The epidermis is persistent. The cortial parenchyma consists of twenty or more layers of thin-walled, somewhat irregular cells, and small intercellular spaces. These parenchyma cells are filled with small starch grains. The cells of the endodermis do not differ materially from the cells of the cortex. Projecting into the vascular region and lying between the phloem and xylem plates, are other broad, primary, medullary rays much wider in the region of the sheath, gradually tapering to a point, toward the center. The phloem elements occur in arched area between the medullary rays. The cambial elements lie between the xylem and arched phloem. The elements of the xylem consist of scalariform ducts and parenchyma cells which are thin walled.

Stem. In numerous specimens examined by us the shoots coming from the roots had small scales and buds along the sides; these for the most part do not develop but can do so when the strong terminal bud is cut off or injured. The microscopic structure consists of an epidermis of a single layer of cells, slightly longer than wide with the outer wall thicker than the lateral walls and carrying a brownish pigment. This is followed by the cortex consisting of many layers of thin walled irregular cells, in which starch and other reserve food products occur. The intercellular spaces are small. The fibrovascular bundles are arranged in a circle and are of the collateral type. The sclerenchyma elements are arranged across the outer and inner portions of the bundle. The phloem is situated between the sclerenchyma and the intrafascicular cambium. The tracheary elements vary with the size of the bundle. These elements consist of spiral, scalariform, and ringed ducts.

Conclusion. The most important method of propagation in the Canada Thistle is by means of the large roots by which the plant spreads through the ground. Such stems as do not occur in the ground come from the adventitious buds on the roots. The seminal roots descend into the soil and later form these adventitious buds. Under some conditions, especially when the plant is injured or when a new shoot is produced in the spring, adventitious buds may be found on the stem.

Solanum carolinense L. Horse Nettle.

The roots and stems of some species of the Solanaceæ have been studied by Gerard[34], also by Costantin[35].

Stem. The twisted woody stem with its numerous lateral roots resembles the root in a very striking manner; in fact it is difficult to distinguish root from underground stem except by microscopical examination. During the winter it dies back near to its origin in the root. The thick walled epidermis

[32]L.c:13.

[33]Con. Bot. Dept. Ia. St. Coll. Agr. and Mech. Arts. 16.

[34]l.c. 375, *pl. 18 f. 53-64.*

[35]l.c. 132.

surrounds the cortical parenchyma, also thick walled in which are stored large, eccentric starch grains which resemble those found in the potato tuber. The fibrovascular bundles are of the open collateral type, with sieve elements next to the cortex, the xylem next to the pith and separated from the phloem by the cambium. The medullary rays extend from the cortex to the pith and contain a few starch grains. The parenchyma cells of xylem are thick walled.

Root. The tortuous roots vary a great deal. In younger specimens they are somewhat slender, becoming thick and hard with ages, lightly brown in color with strong odor. They extend vertically into the soil from one to four feet or even five feet. Numerous adventitious buds are produced along the course.

A microscopical study shows that the organs which produce the buds are roots; these are the usual radial bundles, but the medullary rays secondary and primary are small and lie between the xylem elements. In the secondary structure a few layers of cork cells are developed and underneath a large number of parenchyma cells with walls somewhat thicker than those of the cork cells. These are abundantly filled with large starch grains and a considerable quantity of protein matter. The bulk of the root consists of the cortex. The xylem is separated from the cortex by a well defined area consisting of the endodermis a few layers of very thin walled cells. The medullary rays are harrow and extend into the xylem area between the bundles. These cells also contain starch grains. The xylem elements consist of scalariform and pitted ducts.

Asclepias syriaca L. Milkweed.

Roots. The roots of Milkweed have been traced in the soil for fourteen feet. They are generally horizontal though occasionally vertical. A single root removed from the soil and placed in a moist place at once produced adventitious buds along its surface. At very short intervals several dozen of these buds could be made out with the naked eye; many more could be made out when sectioned.

The roots are whitish and much thickened. Microscopically the roots show that the bundles are of the radial type. The structure in an older root shows thin walled epidermal cells nearly isodiametric although in some cases longer than wide. Underneath the epidermis there are two or three layers of thin hypodermal cells. The cortex is differentiated into two parts, the outer portion of large irregular thin walled cells and small intercellular spaces and the inner cortical region of cells which become smaller toward the endodermis. The cells of the cortex contain a large number of small starch grains and compound calcium oxalate crystals. In secondary growth the xylem consists of bundles of scalariform ducts varying in number from one to five, which are scattered throughout the parenchymatous tissue of the vascular region. Starch grains and calcium oxalate crystals are also found in this parenchymatous tissue.

Stem. The difference in the origin of lateral roots and that of adventitious buds on the root was studied somewhat at detail in the Milkweed.

Lateral roots originate endogenously within the vascular bundles and with a well defined protoxylem push through the cortex. On the other hand stems originate possibly from a single cortical cell just underneath the epidermis. This cell becomes actively meristematic and soon involves other cells which differentiate definitely into plerome and periblem. The epidermis lying just above organizes the dermatogen. Just back of the meristem appears the protoxylem which for some time is entirely separated from the vascular tissue of the root; the tissues of the cortex remain undisturbed for some time. However, the oldest buds which we have sectioned show signs of the vascular region of the stem extending down to the one in the root.

Convolvulus sepium L. Common Morning Glory.

Roots. The small whitish roots usually spring in pairs from the base of the scales. The roots like the rhizomes are extremely fragile. The number and character of the secondary roots differ in different plants.

Stem. The plant propagates freely by its underground stem. The rhizomes are fleshy, dirty white in color, and very fragile. They extend horizontal, vertical, oblique, ascending, or descending from a few inches to two or three feet into the ground. The nodes occur at short intervals. The small roots usually occur in pairs, a point noted by Hitchcock and Clothier. One or more aerial stems spring from the upper nodes.

The anatomy of the stem has been studied by Gerard[36] and Costantin[37], the latter giving a careful description of the anatomical structure. The root stock is essentially a storage reservoir for food, every part but the vascular tissues being filled with starch, a comparatively small part being occupied by the vascular elements. The epidermis consists of somewhat elongated thin walled epidermal cells, underneath which are small hypodermal cells, and small intercellular spaces. The cells vary somewhat in size. The inner layer of the parenchyma cells forms the endodermis. The vascular elements form a ring connected by the cambium. There are four large bundles with a few intervening very small bundles. The bundles belong to the bicollateral type with sieve elements and cambial layers between the endodermis and pith parenchyma. The sieve elements towards the pith form irregular areas. The xylem elements consist of scalariform ducts. The pith parenchyma is sharply differentiated from the cambium.

Convolvulus arvensis L. Bindweed.

Roots. Convolvulus arvensis propagates by means of small creeping horizontal roots. The younger ones are whitish, becoming much darker in color with age. Small branches appear at irregular intervals.

The anatomical structure consists of the following parts, an epidermial layer of rather large cells, a deeply staining hypodermal layer, followed by two layers of cells somewhat longer than wide. The remaining cells of the cortex are large, gradually becoming smaller toward the vascular region. The cells contain a small amount of protein, the starch grains having disappeared at the time of examination in the spring. Some of the cells contain crystals of calcium oxalate. A conspicuous nucleus and nucleolus is present in most of the cells.

The xylem consists of large ducts and thick walled cells, arranged radially with the phloem. The medullary rays extend from the cambium in toward the center of the root which consists of five rays projecting into the xylem.

The root produces adventitious buds. These give rise to short vertical stems which often give rise to other new stems.

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[36] l. c.

[37] l. c.

Agropyron repens L. Quack Grass.

The vegetative reproductive organs are commonly called roots by the laity, but are universally regarded as rhizomes by botanists. A study of the general morphology and histology leaves no doubt as to their stem characters.

Roots. The whitish fragile roots of the rootstock vary in number and they spring from below the scale.

Rhizome. The rhizomes are generally horizontal except where the stems grow toward the surface of the soil, occuring from one inch to 4-5 inches below the surface of the soil. The greater majority, however, are found not more than three inches from the surface. The creeping rhizomes are from 1—3 feet long nearly terete, divided into nodes which are from an inch to two inches apart; at the nodes numerous small roots and buds spring from beneath the scales.

The histological structure of the rhizome is as follows: The epidermal layer consists of thick walled small epidermal cells. Underneath it is the hypoderm, of two or three layers of cells, also thick walled. Between the vascular ring and hypodermal layer are the large cortical parenchyma cells and the endodermis very much thickened toward the vascular bundles. A short account of the histology of the rhizome is given by Fluckiger[38]. Sayre[39] figured the stem, giving no description, while Greenish[40] gives a short description, and a small, unsatisfactory figure. The fibrovascular bundle is of the closed collateral type, consisting of two or three, sometimes four, large tracheae and the small phloem patch between and a little above the tracheae.

To Dr. Trelease of the Missouri Botanical Garden, to Dr. Beal of Lansing, Mich., and to Mr. R. I. Cratty of Armstrong, Iowa, we are indebted for aid in securing some of the material used in this paper, and to Miss King for some drawings.

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[38]Pharmacographia. A History of the Principal Drugs of Vegetable Origin met with in Great Britain and British India. 729.

[39]A Manual of Organic Materia Medica and Pharmacognosy. (Ed. 2.) 440. *f. 298.*

[40]An Introduction to the Study of Materia Medica. 310. *f. 151.*

DESCRIPTION OF PLATES.

PLATE I.

Fig. I. Rhizome of *Lycopus rubellus,* showing scales and roots. Fig. II and III. Root and rhizomes of Canada Thistle (*Cirsium arvense*). Fig. II, *st* underground stem, *r* root, *b* buds from stems and roots, the stem from an adventitious bud at *r;* lateral roots along the stem. Fig. III. *sc* scales on stem, *r* root, *b* young stem from root. Fig. IV. European Bindweed or Morning Glory (*Convolvulus arvensis*). *r* root, *b* adventitious bud, *st* underground stem. Fig. V. Bindweed or Morning Glory (*Convolvulus sepium*). Underground stem with scales at *sc,* and buds at the nodes, also a pair of roots below the scales at *r.* Fig. VI. Wooly Thistle (*Cirsium canescens*) *r* thickened root with stems *s* and *y* from adventitious buds. All figures drawn by Charlotte M. King.

PLATE II.

Upper figure, cross section of the root of Canada Thistle (*Cirsium arvense*) showing the broad cortical parenchyma between the epidermis and the endodermis; inner portion showing radial bundles, the medullary rays extending into the vascular region. Lower figure, cross section of the rhizome of Canada Thistle (*Cirsium arvense*) showing arrangement of bundles. Micro-photograph by Colburn.

PLATE III.

Upper figure. Cross section of root of Milkweed (*Asclepias syriaca*). The vascular cylinder and the cortical parenchyma from which an adventitious bud has sprung. Lower figure. Cross section of the root of Horse Nettle (*Solanum carolinense*). Radial bundles in center; large cortical parenchyma cells densely filled with starch grains. Microphotographs by Colburn.

PLATE IV.

Fig. I. Cross-section of old root of Common Milkweed (*Asclepsias syriaca*). *ep* epidermis, *cor* cortical parenchyma containing crystal receptacles of calcium oxalate *cr, c* cambium, *xy* duct, *pp* parenchyma among the xylem elements. Fig. II, the woody root of Horse Nettle (*Solanum carolinense*). *x* ducts, *pw* woody parenchyma, *p* parenchyma. Fig. III. General view of bundle root of Horse Nettle showing the ducts at *x* and the surrounding parenchyma, less magnified than in Fig. II. Fig. IV. Cross section of outer portion of stem of *Convolvulus sepium. e* epidermis, *p* parenchyma cells with starch, *a* simple and compound starch grains, higher magnification than at *p.* Fig. V. Portion of root of Canada Thistle (*Cirsium arvense*). *Cor* cortex, *par* parenchyma cells of the cortex, *m* medullary rays, *x* ducts, *p* parenchyma, *c* cambium.

PLATE V.

Fig. I. Cross section of root of Bindweed (*Convolvulus arvensis*). *e* epidermis, *h* hypodermal layer, *c* cortex, *n* nucleus, granular cytoplasm evident, *c'* cells of lower portion of cortical parenchyma, *cam* cambium, *p* parenchyma cells surrounding the ducts at *x.* Fig. II. Cross-section of inner portion of root of Bindweed (*Convolvulus arvensis*), showing bundle region, parenchyma cells and five rays. Drawn by Charlotte M. King. Fig. III. Portion of root of Canada Thistle, showing two large ducts and surrounding parenchyma cells. Fig. IV. Cross-section through rhizome of Quack Grass. *e* epidermis with thick walls underneath, *sc* sclerenchyma, *par* underlying thin walled parenchyma, *end* endodermis, *xy* ducts with thick walled sclerenchyma between *ph* phloem. Fig. V and VI. Root of Horse Nettle (*Solanum carolinense*). Fig. V. Cork, cork cells and underneath parenchyma cells and starch grains. Fig. VI. Cortical parenchyma cells with starch grains.

Roots and rhizomes of I *Lycopus rubellus,* II and III *Cirsium arvense,* IV *Convolvulus arvensis,* V *C. sepium,* VI *Cirsium canescons.*

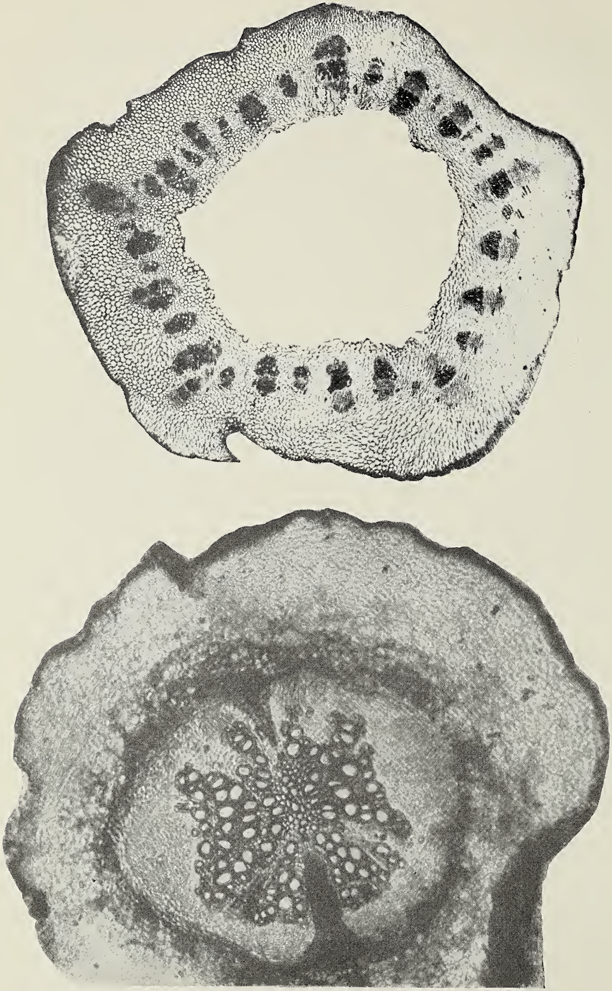

Plate II. Upper figure, stem, lower, root of *cirsium arvense*.

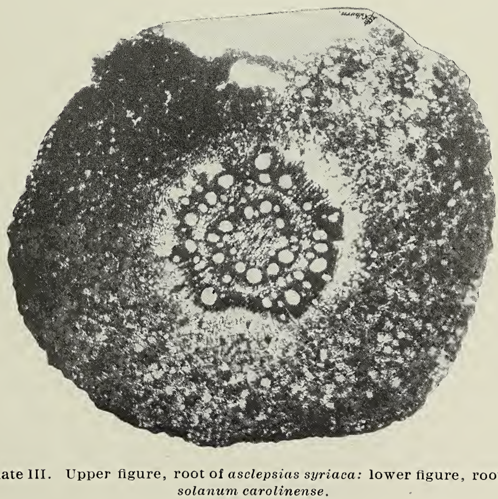

Plate III. Upper figure, root of *asclepsias syriaca:* lower figure, root of *solanum carolinense*.

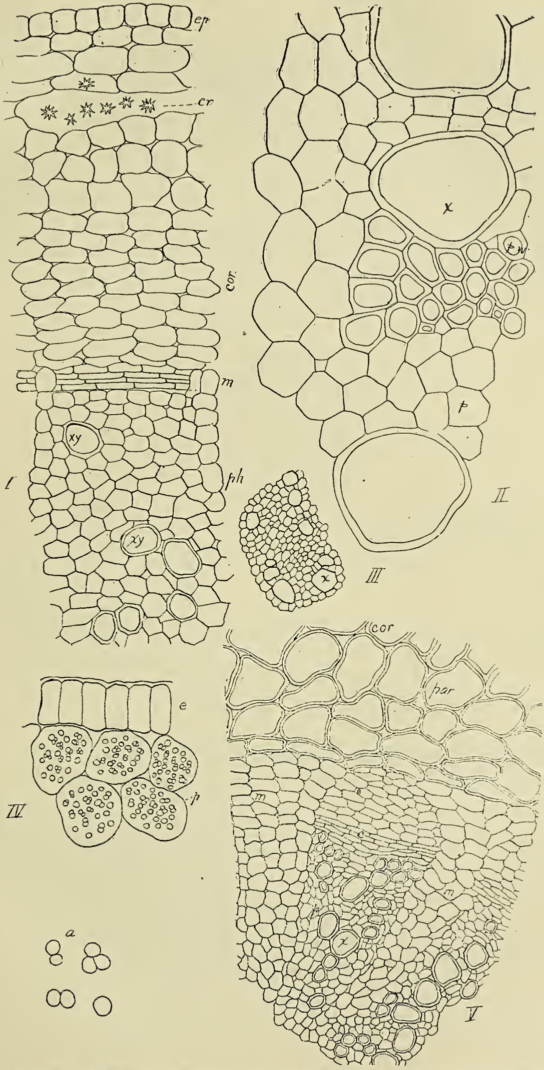

Plate IV—I root of Asclepias syriaca, II and III root of *Solanum carolinense.* IV stem of *convolvutus sepium.* V root of *cirsium arvense.*

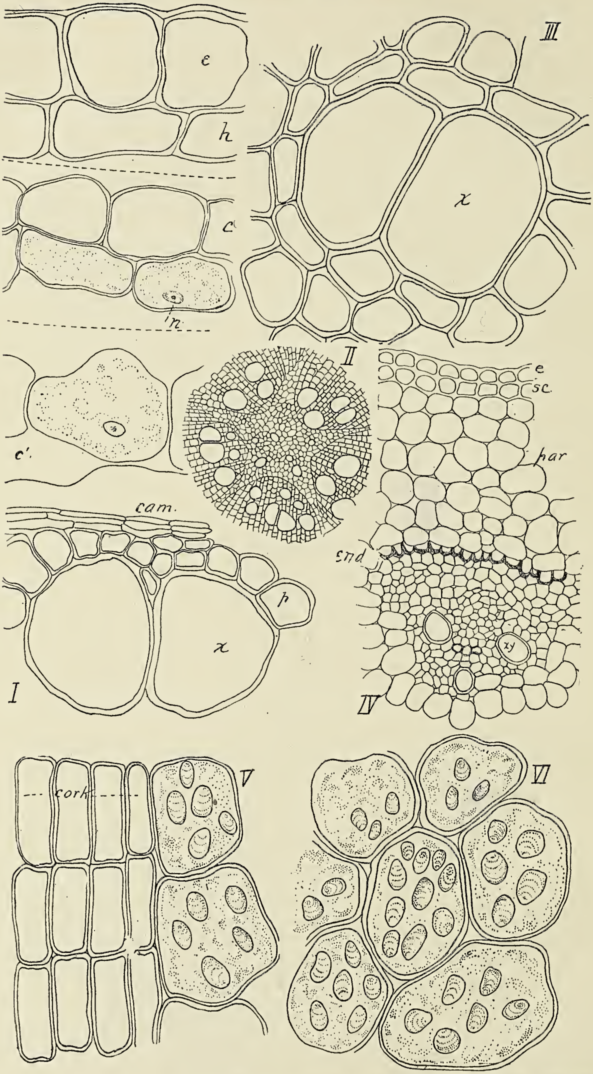

Plate V—I and II Root of *Convolvulus arvensis*. III Root of *Cirsium arvense*. IV Quack grass stem. V and VI Root of *Solanum carolinense*.

NOTES ON FACTORS IN FUNGUS DISEASES OF PLANTS, WITH RECORDS OF OCCURRENCES OF PLANT DISEASES AT AMES FOR A PERIOD OF TWENTY-FIVE YEARS.

BY L. H. PAMMEL AND CHARLOTTE M. KING.

STATEMENT OF THE PROBLEM.

It is important in a study of plant diseases to understand the causes of wide-spread epidemics; notes on the prevalence of diseases, and their seasonal and geographical distribution, are an aid to this knowledge.

LITERATURE ON THE SUBJECT OF PLANT DISEASES.

Some Iowa Publications. In 1882 was begun by L. H. Pammel a series of notes on fungi common in Iowa, especially in the vicinity of Ames. These notes have been presented in various publications as follows:

The Asparagus Rust in Iowa. Bull. Ia. Agr. Exp. Sta. 53:60-67.
Bacteriosis of Rutabaga. Bull. Ia. Agr. Exp. Sta. 27:130-134.
Corn Molds and disease. Bull. Ia. Agr. Exp. Sta. 54:250.
Corn Smut. Proc. Ia. Acad. Sci. *1*:95-96.
Diseases of plants at Ames, 1894. Proc. Ia. Acad. Sci. 2:201-208. 1894.
Experiments with fungicides. Bull. Ia. Agr. Exp. Sta. 16:315-329.
Fungus diseases of grasses. Bull. Ia. Geol. Survey. 1:185-292.
Fungus diseases of grasses. Bull. Ia. Agr. Exp. Sta. 54:250-344.
Fungus diseases of plants and their remedies. Rept. Ia. Hort. Soc. 3:440-444.
The most important factor in the development of rust. Agr. Sci. 8:287-291.
New Fungus diseases in Iowa. Jour. Mycology 7:95-103.
Notes on some fungi common during the season of 1892 at Ames, Iowa, Agr. Sci. 7:20-27.
Potato-rot and its prevention. Bull Ia. Agr. Exp. Sta. 27:120-130.
The potato-rot fungus. Press Bull. Ia. Agr. Exp. Sta. July, 1903.

Prevention of corn and oats smut. Bull. Ia. Agr. Exp. Sta. 20: 721-728.
The Apple Rust and Cedar Apple fungi in Iowa. Bull. Ia. Agr. Exp. Sta. 84:2-55.
Some diseases of plants common to Iowa cereals. Bull. Ia. Agr. Exp. Sta. 18: 488-505.
Some fungus diseases in Iowa forage plants. Proc. Ia. Acad. Sci. *1*:93.
Some unusual fungus diseases of Iowa during the summer of 1903.
Treatment of fungus diseases 1892. Bull. Ia. Agr. Exp. Sta. 20:711-712.
Treatment of spot diseases of the cherry and currants, and potato blight. Bull. Ia. Agr. Exp. 20:716-720.
Treatment of some fungus diseases. Bull. Ia. Agr. Exp. Sta. 17: 419-443.
By Pammel and Carver. Proc. Ia. Acad. Sci. 2:201-208.

Some years ago, Dr. C. E. Bessey[2] published occasional notes on the abundance of fungi in Iowa. Dr. Halsted[3] also published notes on the abundance of certain species of fungi in the vicinity of Ames. Notes dealing with the abundance of American Fungi have been reported by many other investigators[4]. Dr. Erwin F. Smith, in a paper on the peach curl[5], calls attention to the climatic conditions favoring the spread of peach curl, and Dr. Halsted[6] kept a record of the abundance of certain fungi in New Jersey. F. C. Stewart[7] has made a series of experiments in the control of potato diseases of New York, giving notes on abundance.

GENERAL PUBLICATION NOTES.*

For a number of years, Mr. Orton of the United States Department of Agriculture, Bureau of Plant Industry, has kept a record of the important diseases occurring in different parts of the United States. These records are based upon information received through assistance of Bolley, Carleton, Heald and other botanists in different states. Dr. Salmon[6] has, for a number of years, called attention in *Gardener's Chronicle*, to the spread of Powdery Mildew of the gooseberry. In Europe records have been kept by many investigators[9].

THE NATURE OF DISEASE.

Prof. Marshall Ward says[10], "Disease, therefore, may be said to be a variation of functions in directions or to extents, which threaten the life of a plant, the normal in all cases being the state of the plant characteristic of the

*Stewart, Eustace & Sirrine. Potato Spraying Experiments in 1902. Bull. N. Y. Gen. Agr. Exp. Sta. *221*: 236-261.

Stewart, Eustace & Sirrine. Potato Spraying Experiments in 1903. Bull N. Y. Gen. Agr. Exp. Sta. *241*:251-292.

Stewart, Eustace & Sirrine. Potato Spraying Experiments in 1904. Bull. N. Y. Gen. Exp. Sta. *264*:95-204.

Stewart, Eustace & Sirrine. Potato Spraying Experiments in 1905. Bull. N. Y. Gen. Exp. Sta. *279*:1-16.

Stewart, Eustace & Sirrine. Potato Spraying Experiments in 1906. Bull. N. Y. Gen. Exp. Sta. *290*:238-321.

Stewart, French & Sirrine. Potato Spraying Experiments in 1907. Bull. N. Y. Gen. Exp. Sta. *307*:439-463.

[2]American Naturalist. *20*:806; *21*:666.

[3]The Ash-leaf Rust. Bull. Dept. Bot. Ia. St. Coll. Agr. and Mech. Arts. *1886*:55.

[4]Jones and Morse, Potato Diseases and Their Remedies. Ann. Rep. Vt. Agr. Exp. Sta. 1904-1905: 272-291; 1903-1904: 336-402; 1902-1903: 155-156.

[5]Jour. Mycology. *6*:107-110.

[6]Notes upon Peronosporeae for 1892. Rep. N. J. Agr. Exp. Sta. *1898*: 276; *1907*: 440.

[7]Potato Diseases of Long Island in the Season of 1895. Bull. N. Y. Agr. Exp. Sta. *101*: 70-86.

[8]A Monograph of the Erysiphaceae. Memoirs of the Torrey Botanical Club. Vol. *9*:71.

[9]P. Magnus. Verzeichniss der von 11 August bis September in Bayern gesammelten meist parasitischen Pilze. Separat. Berichte d. Bayrischen Bot. Gesellsch. zur Erforschung der Heimischen Flora.

[10]Disease in Plants: 91, 93.
De Bary. Comparative Morphology and Biology of Fungi, Mycetozoa and Bacteria.

species. Clearly then the idea of disease implies danger of premature death, and probably this is as near as we shall get to a satisfactory definition."

"If we agree that a living plant in a state of health is not a fixed and unaltering thing, but is ever varying and undergoing changes as its life works out its labyrinthine course through the vicissitudes of the ever-varying environment, then we cannot escape the conviction that a diseased plant, so long as it lives, is also varying in response to the environment. The principal difference between the two cases is, that whereas the normal healthy plant varies more or less regularly and rhythmically about a mean, the diseased one is tending to vary too sudenly or too far in some particular direction from the mean; the healthy plant may, for our present purposes, be roughly likened to a properly balanced top spinning regularly and well, whereas the diseased one is lurching here, or wobbling there, to the great danger of its stability. For we must recognize at the outset that disease is but variation in directions dangerous to the life of the plant. Health consists in variation also, but not in such dangerous grooves. That the passage from health to disease is gradual and ill-defined in many cases will readily be seen."

"Now take the case where the roots are maintaining their maximum functional activity, but the leaves—owing to want of light, too much moisture or too low a temperature of the air—are functionally depressed. Here we get a state of oversaturation with water set up, the tissues are turgid to bursting point, what supplies do traverse the sieve-tubes, cortex, etc., do so slowly and are excessively diluted, and the cambium again forms less wood, but the lumina of the vessels are larger and the lignification less complete. Growth in length is excessive, but more leaves are formed, though they are apt to be abnormally thin and may be small. Little or no reserves are stored anywhere, and the watery tissues contain dangerously diffusible substances which may render them an easy prey to parasitic fungi. Here again, however, if the disturbance of equilibrium has not gone too far, and if the season permits, the new leaves may come into full activity and the situation be saved by transpiration and assimilation gradually increasing and restoring the equilibrium. But, as before, the plant has suffered, and shows the effect in its weak shoots, retarded flowering, and other ways."

"Such plight as is here described may actually be attained in greenhouses where over-watering is the fault, and even in the open it is not uncommon in rainy summers, or in plantations where dominant trees get the upper hand and partially shade more slowly growing species, or in fields where rank grass is allowed to overwhelm crops of lower stature."

Plants like animals are sensitive, and the maintenance of health is dependent on its sensitiveness. The healthy plant therefore manifests this in the greatest degree. Health, therefore, is a condition in which the reaction between the organism and the surroundings are perfect. The condition, as J. Reynolds Green[10a] says in which the relationship to each of these factors (*light, temperature and moisture*) is satisfactory is generally spoken of as one of tone, and the influence which each exerts when it affects the plant uniformly is spoken of as a *tonic* influence."

[10a]An Introduction to Vegetable Physiology, 358.

TWO KINDS OF DISEASES.

Diseases of plants may be grouped under the following main heads; (1) so-called physiological diseases, due to the action of the non-living environment, such as the soil, atmosphere, temperature and light, (2) those produced by living plants and animals.

FACTORS OF ENVIRONMENT IN PLANT DISEASE.

THE PLANT AN ORGANISM RESPONSIVE TO OUTSIDE CONDITIONS.

A new era is approaching in vegetable pathology, in which the plant is the center. The lamented H. Marshall Ward[11] has well put it in the following words, "Until comparatively recent times it was the habit of farmers, foresters, planters and gardeners, all the world over, to look upon the plant as a mere item or as a mystery of importance in their calculations, and to regard the soil as the 'chief factor in their studies. Now all is changing, and the world is gradually awakening to the recognition of the truth that the soil and the clouds and the atmosphere are merely reservoirs of more or less inert materials, from which the living plant draws its supplies, and works them up by means of energy focussed from the sun, into new plant substance."

The life processes of all plants are essentially similar. The green plant constructs its material from carbon dioxide and water, but carbon dioxide is not food for higher plants any more than it is for the fungus. The higher plant as well as the fungus feeds on the carbohydrates, made by the green plastids called the chlorophyll grains. The plant then is a living machine making food out of raw material, breaking up the carbohydrates and making the living protoplasm, a highly complex substance, thus utilizing the energy of the sun, and storing the material made for future use. This stored material is used to build and construct new protoplasm, cells, and to repair waste. The activities of the plant will depend on conditions from without. Every living plant is therefore influenced by certain factors; these may be grouped under soil, heat, light, moisture, air and living organisms.

In order therefore to protect plant life from the invasion of fungus diseases, we must have accurate knowledge both of the diseases and the conditions which induce them.

Soil and Air. The soil in which the root hairs of the plant occur, consists not merely of dead organic matter but of living organisms as well, which play an important part in the activities of the plant. These organisms not only require organic materials, but oxygen, to carry on their work. Near the surface the decomposition of organic matter goes on much faster than in the subsoil, because there is more oxygen present, and the conditions for constructive work are more favorable. A raw prairie soil seems to be less favorable for decomposition of organic matter than a thoroughly tilled soil. This consideration is intimately connected with the diseases of plants, as will be shown under the heads of rust.

Soil and Moisture. Another factor in connection with soils is the relation they bear to the solutions they yield when in contact with water. Some salts are held, others pass. Some soils hold water more than others. This is a factor of utmost importance to the plant in health and disease.

Light. Too much moisture may lead to disease, especially when there is not sufficient light, for it may make the tissues so delicate that the plant is

[11]Disease in Plants. 1.

ready for the entrance of fungi. Especially is this true of the spores of rust fungi which under warm and humid conditions germinate and then readily enter the host plant.

Acclimatization. Many plants of arid regions are affected with fungi, though of course never so seriously as in more humid regions. The plant itself for want of acclimatization may become subject to disease, as will be shown later. The whole subject of health and disease is a complicated one and involves a great many factors. For a discussion of some of these problems the works of Marshall Ward[12], Galloway[13], Bolley[14], Sachs[15], Pfeffer[16], Jost[17], Kuster[18], Tubeuf[19], Sorauer[20], De Bary[21], Wolf and Zopf[22], should be consulted.

FUNGI AS THE CAUSE OF DISEASE.

Many years ago the German chemist Liebig[23] attached much importance to chemistry in a study of the diseases of plants. He argued that in the case of potato rot the plant is diseased and therefore yields to the attacks of the potato-rot fungus.

It was long thought by the followers of Liebig that the analyses of dead plants or the soil which contained them would reveal the cause of disease.

Later the studies of Boussingault changed the attitude of agriculture towards these problems, and the experiments of Sachs revolutionized the whole subject of plant physiology.

De Bary[24] took a view of the matter different from that of Liebig because it had been conclusively shown that apparently healthy plants may be inoculated by a fungus and produce the characteristic disease.

By the introduction of pure cultures of fungi and bacteria, a new era of investigation has been introduced which no longer leaves any doubt about the causal relationship of disease and the organism. For a study of parasitic fungus diseases the same rules should apply as in a study of bacterial diseases in animals and plants.

THE KINDS OF PARASITIC FUNGI.

The parasitic fungi have been grouped with regard to relationship to host under the following heads by Tubeuf:

1. Epiphytes: (a) with haustoria which only sink into the outer membranes of the host; (b) with haustoria penetrating into the cavity of the host-cells.

2. Endophytes: (a) with a mycelium which grows in the walls of the host-cell, and is generally nourished without the aid of haustoria; (b) with a

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[12] Disease in Plants.

[13] The Health of Plants in Greenhouses. Yearbook U. S. Dept. Agr. *1895*:247.

[14] Encyl. of Agr. *2*:47-53.

[15] Lectures on the Physiology of Plants.

[16] Physiology of Plants. Pflanzen-Physiologie.

[17] Lectures in Plant Physiology.

[18] Pathologische Pflanzenatomie.

[19] Diseases of Plants. Engl. translation W. G. Smith.

[20] Handbuch der Pflanzenkrankheiten.

[21] Untersuchungen uber die Brandpilze und die durch sie verursachten Krankheiten der Pflanzen.

[22] Krankheinten der landwirthschaftlichen Nutzpflanzen durch Schmarotzerpflanzen.

[23] Lectures in Agricultural Chemistry.

[24] De Bary. Comparative Morphology and Biology of Fungi, Mycetozoa and Bacteria.

mycelium which grows in the intercellular spaces only, and is nourished with or without haustoria; (c) with a mycelium which penetrates into the host-cells and becomes an intracellular mycelium; (d) lower fungi which live completely in host-cells."

HOW FUNGI ARE SPREAD.

The mycoplasma theory of infection with the seed in view of recent researches is untenable.

Dr. H. Klebahn[25] in discussion of the mycoplasma theory of Eriksson, cannot agree with Eriksson in regard to this kind of infection. The *Puccinia glumarum* did not appear when the sources of infection were absent. *Puccinia simplex* and *R. graminis* made their appearance only when the plants were placed in the open air. Seeds coming from plants that had been badly rusted the year before produced very little rust when sown. Infection according to this author is due largely to spores carried by animals and wind. It also appears that plants badly rusted in the fall and permitted to remain in the field produce very little rust in the succeeding summer.

Agencies of Infection. The wind, dew, and rains, insects, snails, and other animals, as well as human agencies, are responsible for the spread of fungus diseases.

The Wind an Agent. That the wind sometimes plays an important part in the spread of fungus diseases has been repeatedly observed.

An interesting case is noted by Dr. Halsted[26]. The particular field in question had been cut off earlier in the season so that a new growth made its appearance, and on September 6th the asparagus brush was about four or five feet high, but the rust was only on one side of each plant. The rusted side was at right angles to lines drawn from an old and very badly rusted patch of asparagus about forty rods away and the source of infection was undoubtedly the old bed.

Dr. Sturgis[27] calls attention to the infection of lima bean mildew by the wind. Thus he observed the disease abundant on a farm for a distance of about one mile on a straight line from the Station but none were observed at this time, August 14th, on the Station vines. On the following day two mildewed pods were brought from the infected farm and the mildew rubbed upon the pod of a single healthy plant at the end of each row. The wind varied from northwest to northeast and within a week the mildew appeared abundantly from the two infected pods and from this plant swept on to the adjacent plants.

Water as an Agent. Water sometimes helps to scatter fungi as in case of zoospores of the potato rot fungus which are motile. Moist leaves coming in contact with each other through the wind, must be a factor of some importance in the dissemination of such diseases as the Downy Mildews, where zoospores are formed. These diseases are always more important during warm years when rains are frequent and the atmosphere is humid.

Fungi Spread by Insects. We have seen many leaves of grapes affected by powdery mildews which showed the outlines of the movements of snails over the leaf, the disease appearing[28] where the slimy body of the insect came in contact with the leaf. Who has not seen numerous flies feeding on the

[25]Zeit. Pflanzenk. *1898*:321. 1900:70.
[26]Torr. Bot. Club. *25*:159.
[27]Bot. Gaz. *25*:193.

sphacelial stage of ergot? These flies in favorable season like 1907 in Iowa, produce a wide-spread infection. The cabbage butterfly is largely responsible for conveying not only the cabbage rot (*Pseudomonas campestris*) but a beneficial bacterial disease destructive to the larvæ of the same insect. Insects are also largely responsible for carrying the rust of the red cedar (*Gymnosporangium macropus*) to the apple tree. The cedar apple fugus furnished a very attractive food for them. Bees, the active pollinators of the apple, also carry the bacteria of apple blight, which is found according to Waite in the nectar of the blossoms of the apple. Aside from this conveyance, flies feeding on the exudate on the stems affected by pear blight also convey the disease. Insects feeding on rust spores convey the same to neighboring plants.

Flies and other insects aid in scattering spores of the spot disease of the cherry. These spores cling together in a sticky tendril-like mass; this material is said to have a sweet taste. Water also aids in dissemination of spores of cherry spot disease.

The common Stinkhorn (*Phallus impudicus*) which frequently causes trouble in orchards and gardens because of the bad odor, is chiefly disseminated by flies that feed on the spores.

Ergot (*Claviceps purpurea*) is commonly carried from cultivated to wild rye and other grasses, by common flies which feed on the honey dew stage (*Sphacelia*) of the fungus.

Gardiner[29] describes how contrivances for assisting plants to maintain themselves in the struggle for existence are found in fungi and algæ; as in the case of Queensland fungus, Clathrus, which has orange red color, strong smelling spores, and is enveloped in a sweet mucilage, thus using the same advertisements, color, scent, and sweetness, employed in higher plants. The mildew of alder has hooked fruits, which are possibly carried about by tiny *Acari*. Spores are shot out with some force from the mycelial filaments of the fungus that attacks flies. The spores of *Sclerotinia Vaccinii* have an almond smell, and are gathered by bees with pollen, and conveyed from one plant to another.

The influence of insects in carrying diseases is well illustrated in the common lima bean mildew (*Phytophthora phaseoli*). Dr. Sturgis[30] calls attention to the structure of the flower of the lima bean and its adaptation to cross pollination. The insects (bees) that pollinate the flowers are largely responsible for conveying the disease. Dr. Sturgis says:

"Further investigation confirmed this view. I have called attention to the enclosed and protected position occupied by the pistil; this obtains until the flower is visited by an insect of considerable size, generally a honeybee. The projecting wing-petals offer a convenient landing place, and, as the bee alights on them, his weight deflects both wings and keel, the style is protruded from the keel, the bee's abdomen brushes over it, and in his efforts to reach the bottom of the flower the petals are forced apart, the base of the ovary exposed and the bee's head comes in contact with it. Thus cross-fertilization is secured, but if the bee has, by chance, touched a mildewed pod with either head or abdomen, fungous infection no less surely occurs. It will be noted that the only portions of the pistil touched by the bee are the base of the ovary and

[28]Miss Estelle D. Fogel Rep. Ia. State Hort. Soc. *41*:105. 1907.
[29]Gardiner Abstr. in Nature. *41*:91.
[30]Bot. Gaz. *25*:192.

the style. An examination of scores of flowers showed that in the majority of cases they were infected, and in these cases, without exception, the points of infection were identical with the spots touched by the bees."

Fungi Spread by Other Animals. The spores of many fungi pass uninjured through the digestive tract of animals. It is probable that some of the spores of corn smut may pass the digestive tract of herbivorous animal uninjured, just as corn and other cereal grains often do. Corn smut is more resistant to heat than corn is; it is probable that the digestive juices will not entirely destroy the spores of corn smut. The spores of many fungi are accidentally carried by insects by attaching themselves to the body of insects, birds, or other animals. Birds like woodpeckers may convey many wood fungi by opening holes in trees; the same is true of boring insects. In a disease of cotton studied by one of us in 1889, it was shown that mice and other rodents scattered the sterile mycelium of the Oozonium.

Fungi Scattered by Explosive Properties. Many fungi have explosive properties but there are few of these among our cultivated crops. The Morchella, or Morel, forcibly ejects its spores; so too, the cup-fungus, or Peziza, from which the spores are ejected; the Polyporus and various wood-fungi, and the Agaricus and other mushrooms, scatter their spores in the same manner.

Fungi Spread by Farm Tools. The pruning knife may be the cause of the spread of many diseases like pear blight. A knife used for cuttings when in contact with a contaminated soil may frequently contaminate many cuttings as in the Botrytis disease of the House Geranium. Farm implements used to cultivate the soil may spread many root diseases as shown by one of us in connection with the root-rot of cotton and other root diseases of the orchard and garden. The number of instances of such diseases might be multiplied.

SOIL MOISTURE AND FUNGUS DISEASE.

Asparagus Rust. Regarding infection Prof Ralph E. Smith[31] makes interesting observations. After the statement that the marked freedom from rust of two seasons was due to unusual rainfall, he says: "In the dry seasons and upon the drier soils lack of moisture unquestionably reduced the vitality of the asparagus plants. Consequently they become more susceptible to disease and suffered in inverse proportion to the amount of soil moisture available."

The observations of Mr. Sirrine[32] led to the conclusion that the relation of atmospheric moisture in the form of dew or fog is the most important factor of this nature in the development of asparagus rust.

Stone and Smith[33] found a difference in the prevalence of the disease according to the moisture retaining properties of the soil, the trouble being worse upon the drier soils.

Celery Root Rot. Mr. J. N. Hook[34] found that a serious root rot of celery in Ohio was caused by a species of rhizoctonia. The disease appeared in soils in which celery had been grown for several years and the diseased spots seemed to occur where the ground was lower or not well drained and the soil condition seemed to be largely responsible for it.

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[31]Bot. Gaz. 38:19-43. Bull. Cal. Agr. Exp. Sta. 165:51-58.
[32]N. Y. Geneva Exp. Sta. Bull. 188.
[33]Bull. Mass. Hatch Exp. Sta. 61. Ann. Repts. Mass. Hatch Exp. Sta. *12, 14, 15.*
[34]Cir. Ohio Agri. Exp. Sta. 72:6.

Grain Rust. There is every evidence that rusts, in particular *Puccinia graminis* and *P. coronata* are more common in very moist soils than in drier places. We have observed rust very severe in low fields, when on adjacent and higher ground there was less rust. The poorly drained fields always suffered more than the soils well drained. Mycological literature is abundant on this point.

WEATHER AND FUNGUS DISEASES.

The weather refers to the state of the atmosphere; it has reference to degrees of warmth, cold, moisture and drought. Certain conditions of weather are often responsible for wide spread epidemics of plant diseases. Where the organic matter of the soil undergoes rapid disintegration accompanied by humid, warm conditions the small grains are affected with rust. The warm humid conditions always lead to the attacks of downy mildews. Cool weather though accompanied by frequent rains is not conducive to the severe attacks of rust.

Dr. Halsted[35] reports that after an early spring of unusual cloudiness and precipitation in New Jersey in the year 1898, the hollyhock rust was very abundant and destructive; cedar apple fungus of great frequency; exoascus remarkably abundant; peach curl never before so wide-spread.

The years 1891 and 1892 were dry ones in which there was no outbreak of fungous troubles; the year 1894 had a dry summer. The year was remarkable for a most widespread and destructive fire-blight. The month of May had unusual precipitation followed by a superheated period of ten days. Then came the blight, which seriously affected all pear orchards. In the same year cherry leaf spot disease are unusually abundant.

The year 1896 was dry, with June and July rainy. During this time asparagus rust spread in Eastern United States to an alarming extent.

Dr. Paul Sorauer[36] in a discussion of the problems connected with the sensitiveness of plants with regard to parasitic fungi, notes that the attacks are due to the injuries of frost, etc., and that frost is one of the most potent factors in connection with the attacks of fungi. Plants that are variously colored or blanched are much more subject to diseases than the green plants. This writer considers that it is important to consider plant hygiene, to prevent disease by culture and to develop immunity.

He states that in the winter of 1900-01, there was little frost in Germany, but from observations made by numerous persons in Germany it was found that where the eastern and the northern winds removed the snow that the plants on such places became more affected with rusts; furthermore that a heavy soil containing considerable moisture when grain was sown early was less subject to rust than other places. An experiment made with rye indicated that when the moisture is too great and the temperature too high that the plants were affected very much as with frost.

Dr. A. B. Frank[37] in a paper on the subject of rusts gives as the characteristic influences of this disease the following: "That the spores of the rust

[35]The Influence of Wet Weather upon Parasitic Fungi. Bull. Torr. Bot. Club. 26: 381-389.

[36]Mitt. d. Deut. Landw. Gesellsch. 1900:185.

[37]Nachrichten a. b. Klub d. Landw. 1898:388-389.

germinate readily only when they have been submitted to the atmosphere for the winter; that saltpeter fertilizer favors the development of rust. He cites the experiments conducted in 1894 which was very favorable to rust, to show that varieties from American, Indian and other foreign sources, are particularly subject to rust. The investigation carried on by the German Agricultural Society since 1892 shows that hybrids of the square head were a little subject to the disease and varieties like Dumel were comparatively free from rust.

Exoasceae Influenced by Weather. Plum pocket (*Exoascus pruni* and *E. communis*), Peach curl (*Exoascus deformans*) are excellent illustrations of fungi influenced in their development by meterological conditions. Peach curl was destructive in Southern Iowa where peaches are grown; in 1907 many correspondents reported it as destructive. In 1908 there was little of it. Some trees in the vicinity of Ames showed much of it in 1907, the same trees in 1908 had none of the fungus. Puffed branches or plum pocket (*E. communis*) was abundant in 1907 in many parts of the state. It was also reported in 1908 but not nearly as destructive. The curl on oak was also common in places in this state in 1907. The season of 1907 will show somewhat unusual conditions. May was unusually cool with late frosts. These conditions seem to be very favorable for the development of these fungi.

The senior author of this paper during the present season has had unusual opportunities for studying several of the Exoasci in the Rocky Mountains, from Eastern Colorado to Utah. In all of these places the Exoasci were abundant. The leaves of the Rocky Mountain oak (*Quercus undulata*) were much diseased at all points visited, Colorado Springs, Palmer Lake, Placerville, Colorado, Salt Lake City, and several other points in Utah.

The *Exoascus cerasi* on *Prunus Virginiana* and *P. Pennsylvanica* was also abundant in Colorado and Utah. Hundreds of leaves were puffed out. One of the most destructive parasites is the Exoascus on the hard Maple (*Acer grandidentatum*); near Logan every tree had nearly all of its leaves spotted from the effects of this fungus. The forests looked blighted. Another common fungus is an Exoascus on the Quaking Aspen, which was common in parts of Colorado.

The conditions in the mountains are unusually favorable for the development of these fungi. The evenings are always cool and the spring backward. It is not unusual in spring and early summer for frosts to occur. The disease appears earlier at lower elevations and later at higher altitudes.

Month	Temperature in degrees			Precipitation in inches		
	1907	1908	Normal	1907	1908	Normal
January	27.9	24.4	23.5	1.	.52	1.12
February	34.9	27.4	24.7	.84	.86	1.18
March	40.7	37.5	33.	.97	.52	1.61
April	43.	44.2	44.2	1.99	.9	1.99
May	47.1	49.1	52.9	2.37	2.19	1.86
June	58.1	59.1	61.4	1.16	.96	1.54
July	66.2	65.6	66.6	2.40	2.6	1.96
August	64.5	----------	65.1	2.13	----------	2.07
September	57.5	58.3	57.7	5.75	3.35	5.71
October	49.1	43.1	46.1	.89	5.97	1.16
November	33.4	----------	34.3	.37	----------	.57
December	25.9	----------	25.	1.02	----------	.95

Mr. W. A. Orton speaking of the epidemic of wheat rust for the year 1904 says:

"Wheat rust (*Puccinia graminis*) this year, 1904, caused very general damage over the whole country, due to the humidity of the atmosphere in the latter part of the growing season, and to lateness of the grain in maturing. In the spring-wheat states of the Northwest the loss from rust was 25,000,000 to 40,000,000 bushels, worth at least $25,000,000. In many instances the rusted fields were never touched by the harvester, and over wide areas the yield was only four to five bushels per acre. The western winter-wheat states also suffered severely, and rust was bad as far east as Indiana and Ohio, though not severe in Maryland. The durum varieties introduced by the department proved notably resistant, though the season brought out great variations in rust resistance even in this group. M. A. Carleton[38], of this Department, has published further results of investigations into the life history of this and several other species of rust."

The weather conditions for 1904 are included in tables and maps accompanying this paper.

Mr. James Berry reports that the season of 1904 in the Upper Mississippi Valley to the Atlantic Coast was generally backward, although the average temperature for the month was generally in excess of the normal. Spring wheat seeding was well advanced over the southern part of the region, by the 7th and 8th of April. Severe rains and snow occurring. The next week, April 18th, was unseasonably cold and germination was retarded. There was considerable snow in the upper lake region during the latter part of the week and considerable frost occurred. Spring wheat seeding was nearly finished in Iowa, Nebraska, southern South Dakota. Little had been done in North Dakota and Minnesota. The week ending April 25th there was freezing temperature throughout the Central Valleys, lake region, New England, and the Middle States. The week ending May 2nd was cool and unfavorable for growth. The week ending May 9th was more favorable. The spring wheat early sown was making good growth. The week ending May 16th as much too cool, with frosts. The week ending May 23d was more favorable except for frosts on the 16th and 17th in the lake region and upper Mississippi Valley. The following week, May 30th, there was excessive moisture from Iowa to Missouri and Oklahoma. The crop of small grain was promising. The week ending June 6th there was excessive moisture and lack of sunshine. The week ending June 13th had unfavorable temperature with too much rain. The outlook for oats was promising. The week ending June 20th continued cool, east of the Mississippi was unfavorable but westward more favorable. The upper Mississippi Valley states suffered from extreme moisture. Rust reported from Nebraska and Iowa. The week ending July 4th was unseasonably cool and unfavorable for rapid growth. On July 11th the weather continued unseasonably cool. Rust reported from Minnesota and Dakota. The week ending July 18th was favorable except in some districts where there was too much rain. The week ending July 25th, too cool with lack of sunshine. The week ending August 1st reports of rust from the spring-wheat section of the country very pronounced. A similar summary for 1900 will show that changeable weather with a great deal of rain and late frost greatly influenced the appearance of rust.

[38]U. S. Dept. Agr. Yearbook. 1904:563.

The Downy Mildews. (*Peronosporeae*). This group of fungi has been studied more carefully with respect to meteorological conditions than any other kind. The years 1895, 1903 and 1905 were particularly favorable for their development. It will be seen from the weather conditions that we had during growing a great deal of moisture accompanied by high temperatures.

The year 1903 will be remembered as very destructive to the potato. In addition to the potato rot fungus (*Phytophthora infestans*) the grapevine mildew (*Plasmopora viticola*) was abundant.

Prof. Guy West Wilson whose work on the Peronosporales, for 1907, has been noted in another place, says:

"*Plasmopora Halstedii* (Farlow)

This species was first observed July 29th in the vicinity of Greencastle, Indiana, where a few infected leaves were found on one or two plants on *Bidens frondosa.* By August 13th the fungus was fairly abundant in this locality and by the 27th of that month scarcely a plant remained uninfected in all the Indiana localities visited. The infection was as complete as any seen during the season, all the leaves being affected and the lower ones killed outright, but no oospores were found. A single clump of *Erigeron annuus* was also found infected." This species was common in Ames in August and September.

"*Plasmopora viticola* (B. & C.)

This species was quite abundant on both wild and cultivated species of *Vitis* when they were first examined in July. Conidia were collected on leaf, petiole, tendril, and young twigs. In some vineyards the disease was responsible for heavy loss of fruit but none of the diseased berries were examined for oospores. Among the twelve specimens collected one was upon seedlings of cultivated grapes."

The Grape Vine Mildew was abundant in Ames and in northeastern Iowa in June and July. It was not abundant later in the season. Spring shoots of the wild grape were badly diseased.

Bremia lactucae Regel. Mildew of Lettuce.

Prof Wilson states that this fungus was "collected on *Lactuca canadensis* in Hamilton and Putnam counties, Indiana, between July 23d and August 3d. All this material had the appearance of being quite old and indicated that the conidia had been produced for some time past. Of the three specimens collected none contained oospores." It was abundant on wild lettuce in June in the vicinity of Ames, none, however, was observed on the cutivated lettuce.

Peronospora alta Fuckel.

Prof. Wilson did not report it as common in Indiana, but it was abundant in Ames in June in 1907, where thousands of leaves were diseased. It was not abundant in Ames in 1908.

Peronospora parasitica (Pers.) Fries. Downy Mildew of Mustard.

This fungus was abundant during the month of May and June, 1907, in Ames, later appearing on other hosts. It was not common in 1908. Prof. Wilson says concerning this fungus:

"During the early spring in New York this fungus attacked great numbers of seedlings of *Lepidium virginicum* but soon run its course. The previous summer the fruiting and inflorescence was frequently destroyed during midsummer, but this season no such attack was noted before reaching Newark, Delaware, where the fungus was evidently just making its appearance. The same host was found sparingly affected in Indiana. Here a single clump of

Brassica nigra and a single bed of *Raphanus sativus* were found infected. No very robust growth of the fungus was observed this season. Of the five specimens (N. Y., one; Del., one; Ind., three) examined the only oospores found were intermingled with those of *Albugo candida* on a pod of *Raphanus*.

Regarding Grape Mildew, Farlow[39] says, "The fungus, like all the other species of the genus, flourishes best in moist warm weather, but seems more tolerant of dryness than any other Peronospora with which we are acquainted."

To quote from the paper of Mr. Guy West Wilson[40]:

"Two important and interesting problems in the history of Peronosporales are (1) the interrelation of meterological conditions and the abundance and development of these fungi and (2) the location of centers of seasonal distribution. These problems necessitate a series of observations extending over a term of years in a given locality and at the same time require the co-operation of observers in localities widely separated in space and climate.

A phase of the subject has been treated by Drs. Orton and Selby in their investigations of the centers of seasonal distribution.

These observations have been confined almost entirely to economic species such as *Pseudoperonospora cubensis* and *Phytophthora infestans*. From these studies on the first species the oospores which have so persistently eluded the collector it appears that this spore form may be elided or only produced at irregular intervals as a means of rejuvenation. The fungus is perennial in Florida and from this center is carried northward by the conidia each season.

From a study of Peronospora in Iowa in 1887, it appeared that the species are suited to a moist season. In general the mildews were found in early spring and after this through the long dry summer, in limited quantities upon plants growing in damp places. During the season from March to August had only 8.32 inches of rainfall.

The Powdery Mildews are much more abundant in a comparatively dry season than in a very moist season. For this reason the Powdery Mildew of the Lilac, Cherry, and Grape are much more common in Iowa during the latter part of the season than during the early part. The years 1895, 1899, 1901 were noted for the abundance of Powdery Mildews.

Dr. Halsted[41] in a discussion of the relation existing between late fall and potato rot, states that in 1897 and 1899 were two seasons particularly destructive so far as potato rot was concerned, in the eastern states. In 1897 the outbreak of potato rot was very unusual and carried away the larger part of the potato crop. He gives the following table:

Year	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	Av.
Rainfall	3.50	10.19	5.62	5.30	4.03	2.72	1.66	4.24	5.50	11.42	5.42

He states further that the fungus disease was not destructive in 1889. "It seems to me that the *Phytophthora* or late blight is quite dependent upon an abundance of moisture in midsummer, and if this relation is noted sufficiently the time may come, it may be predicted with reasonable certainty, that a wet

39On the American Grape-Vine Mildew. Bull. Bussey Institution 1876: 415-425.

40Guy West Wilson. Notes on Peronosporales for 1907. Proc. Iowa Acad. of Sci. *1908*:85.

41Torr. Bot. Club *25*:161.

July will mean a decaying potato crop, unless some successful method of checking this rapidly developing fungus is employed, and contrariwise, a dry midsummer will insure freedom from its ravages.

The Potato Rot fungus (*Phytophthora infestans*) was abundant in Iowa in 1903; along with this mildew many of the other downy Mildews were common like Downy Mildew of the Grape (*Plasmopora Viticola*) destrowing many of the young shoots and even berries of such grapes as the Noah, *Vitis riparia*, Lindley, etc. The Sunflower Mildew (*Plasmopora Halstedii*) was abundant on many composites like the Sunflower, Boot Jack and Marsh Sunflower (*Helianthus*). The years 1900, 1902 were unfavorable for the development of these fungi. These conditions are best shown by the conditions of the rainfall brought out in tables accompanying this paper.

Mr. Norton[42] says, in speaking of late blight of potato, "This disease is not commonly destructive in Maryland, as the summer temperature is not usually sufficiently low for a time long enough for the development of the parasite, though it has caused serious loss in many parts of the United States since 1840, and has been destructive at times as far south as Florida, being no doubt introduced on northern seed."

Fusicladium and *Monilia*. H. Mueller-Thurgau[43] in a paper on the Monilia Disease of branches of Drupaceous Fruits, attributes the epidemic in Switzerland, of that year, to the cold days of March, 1900. In other words the frost was partly responsible for this disease in that branches became less resistant to the Monilia and allowed the fungus to enter easily.

Rudolph Aderhold[44] in a discussion of the development and life history of the relationship of Cladosporium and Fusicladium spores, and the causes that lead to infection thinks that the most favorable temperature for the germination of *Fusicladium pyrinum* is +2° C. and germination is very energetic at 11°. The optimum temperature of the same is 22°, but beyond this there is a rapid decline. Therefore the warm days of spring appear to be especially favorable for the germination of the spores of Fusicladium. The spontaneous appearance of Fusicladium is dependent largely upon the character of the weather, especially moisture, frequent rains are favorable.

SOME FUNGUS EPIDEMICS.

Mildews. It may be interesting to note here that in some years certain species of mildews are particularly destructive to certain host plants.

Salmon[45] states that the mildew of the cultivated hop sweeps in epidemics over some of the European countries in certain years, not appearing in intervals between.

Mr. David Griffiths records an interesting observation of the occurrence of fungi. Beginning with 1892 *E. communis* was not found on Polygonum, a new host, in South Dakota until 1895, when some immature specimens were found in the northern part of the state. The following year it was more frequent and two years later abundant everywhere. Doubtless the fungus occurred in small quantity, though unobserved, previous to 1896.

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[42]Norton, J. B. S. Irish Potato Diseases. Bull. Md. Agr. Exp. Sta. *108*;69.

[43]Schweiz. Zeitsch. f. Obst-Und-Weinbau. 1900. Centralb. f. Bact. u. Par. 2 Abst. *6*:653.

[44]Landw. Jahrb. *29*:541-587, pl. 9-12.

[45]Torr. Bot. Club *9*: 11.

During the present season 1908, we notice with particular severity and abundance the powdery mildew of the catalpa, plum, and cherry. The common powdery mildew of the knotweed has been particularly abundant here for a number of years and this season forms no exception to the rule.

Rusts. The Ash rust was reported by Dr. Bessey as abundant in Iowa in 1884. The same year it was observed in La Crosse, Wisconsin. Since then it has not appeared in these neighborhoods in epidemic form. There must have been a great deal of the teleuto stage of the rust. The *Puccina pruni-spinosa* was common in 1889 on a variety of *Prunus Americana*, the Chippeway in Ames and since has rarely been seen.

Clover Rust. Clover rust upon red clover[45] was not observed in Iowa until August, 1900, and then upon the "aftermath." Later it was found quite abundantly on the College Farm, the diseased plants being seriously affected.

How long the fungus has affected red clover plants in this country and in Iowa is not known, but it is reported on white clover by Arthur in 1884 and was common on this host in Wisconsin in 1883.

Hollyhock Rust. The hollyhock rust, native to Chili, was introduced into France in 1872, and in a short time became general in Europe. It found its way to this country in the year 1886, having been reported from Beverly, Mass. Prof. Farlow[46] records its earliest appearance in the United States. Hollyhocks in the garden of Prof. C. L. Jackson were found to be affected with the disease which was introduced with the seeds imported from Europe. In 1887 it appeared in the Boston Public Garden. A few years later in 1891 it was reported in New Jersey and New York. This was reported by C. E. Hunn[47] in New York in 1889. The writer found it common on the Pacific coast in 1898. This disease has played havoc with hollyhock culture in some parts of the United States.

Asparagus Rust. The Asparagus rust, native to Europe, was unknown to this country prior to 1896, when it was reported in the east. Halsted[48] and R. E. Smith[49] think that the rust started in an epidemic from the North Atlantic states during the fall of 1896. It is now a most destructive enemy to the culture of this plant.

Downy and Powdery Mildews. The Downy Mildew of the grape was unknown in Europe before the introduction of the American grape vines to resist the attack of the Phylloxera. Mr. Salmon gives an interesting account of the spread of the gooseberry mildew in Europe which he thinks may be due to importation of American plants.

The potato rot fungus (*Phytophthora infestans*) was unknown to the botanists of Europe before 1845. This soon spread to many of the European countries playing havoc with the culture of the potato.

Apple Blight. Apple and pear blight was practically unknown on the Pacific coast until a few years ago. It was unknown according to Ralph E. Smith[50] in central and northern California but it had wiped out the orchards in the south-

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[45]Iowa Agr. Exp. Sta. Bull. 13 ;51-53.

[46]Farlow, W. G. Bot. Gaz. *11*:309-310.

[47]A disease of the Hollyhock. Rep. N. Y. Agr. Exp. Sta. *1890*:335.

[48]The asparagus rust ; its treatment and natural enemies. New Jersey Agr. Exp. Sta. Bull. 129 :3-20.

[49]Asparagus and asparagus rust in California. Cal. Exp. Sta. Bull. 165 :5-99. Rept. of Plant Pathologist July 1, 1906.

[50]Univ. Cal. Exp. Sta. Bull. 184 :221.

ern part of the state. This shows that when the source of infection occurs that a disease may become troublesome and serious.

Clasterosporium. Rudolph Aderhold[51] calls attention to the *Clasterosporium carpophilum* which is especially destructive to cherry leaves in Germany, and that the same attacks the younger leaves more readily than the older.

IMMUNITY AND DISEASE-RESISTANT VARIETIES.

Acclimatization. In general acclimatization is the best dependence for immunity from fungus diseases. A plant thoroughly acclimated is more disease-resistant than one not acclimated.

Corn brought from tropical countries and cultivated in Iowa has a strong tendency to become affected by both smuts and rusts.

A case of the kind was referred to by one of us[52], on some corn from the Philippine Islands, a number of years ago; every ear was affected with smut, many nodes likewise containing the same fungus.

A variety of Texas rust-proof oats[53] when grown on the College Campus was found to be more seriously attacked than acclimatized varieties.

During the past few seasons, Mr. Burnett, has had under cultivation a large number of varieties of oats. Invariably the varieties not acclimatized were more subject to rust than other kinds. The Garton oats, well known for valuable qualities, when grown in cooler climates produce smaller crops on account of rust; after having been grown two or three years in this country they are less subject than when first imported. Such acclimated varieties as Early Champion and Khersoen are much freer from rust than the non-acclimated varieties from Europe, the north or from the mountainous districts of our country.

Prof. Bolley[54], commenting upon the stableness of varieties states: "Though I have worked with many varieties and strains of wheat, flax and potatoes and have found them all reasonably stable if given generally stable environment, I have never yet been sure that I have seen a stable plant or a stable strain or variety. Some change is continually taking place and any change I think, may be fixed just in proportion as we know the conditions which originate it."

Prof Bolley says[55]: "The North Dakota Experiment Station has had a very marked success in breeding and selecting flax with a view to gaining resistance to wilt and rust; indeed it has largely solved the problem so far as breeding for resistance in seed crop is concerned."

The work in selection of Clover resistant to *Colletotrichum trifolii*, by Bain and Essay[56] resulted in a decided reduction of the disease.

Of sugar-cane in Hawaii, Mr. Cobb[57] says, "The chances seem distinctly to favor the ultimate securing of resistant varieties that are also highly productive."

The Le Conte pear succeeds best in the Gulf Coast and Southern Atlantic regions being quite free from blight, more so than Kieffer pear.

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[51]Landw. Jahrb. 30:771. Biedermann's Centralb. Agrikultur chemie 32:23.

[52]Pammel, L. H. Monthly Review of the Iowa Weather and Crop Service. 2:9.

[53]Pammel, L. H. Fungus Diseases of Iowa Forage Plants. Pro. Iowa Acad. Sci. *1*:93.

[54]Rept. Am. Breeder's Assn. *4* 1908: 125, 128, 129.

[55]Rept. Am. Breeder's Assn. *4* 1908: 228.

[56]Bull. Tenn. Agr. Exp. Sta. 75.

[57]Cobb, Some Elements of Plant Pathology. 43.

With regard to blight of pears Waite[58] says, "The thrift that makes a tree bear good fruit also makes it susceptible to blight. Check the tree by withholding tillage so that it makes a short growth and bears small fruit and it will be in a better condition to withstand blight than it would were it cultivated."

Some Resistant Varieties. Some varieties of apples have been found to be more resistant to rust than other varieties; Oldenburg, Hibernal, Fameuse and Canada Baldwin in Iowa[59] are more or less resistant.

In observations with rust of the apple, the Mercer County crab was found to become affected by the *Gymnosporangium macropus*, while the Russian variety Tetofsky on which it was grafted, was free.

Within recent years wide infection has resulted to the Wealthy apple from proximity to the Cedar apple fungus on cedar trees. Duchess and its type are quite free from apple scab; Wealthy is quite generally affected.

The Early Richmond and Montmorency cherries are very subject to leaf-spot (*Cylindrosporium padi*).

Immunity from One Disease Caused by Presence of Another. Regarding peculiar conditions obtaining in the relationship of fungus and host, Dr. Halsted[60] observes that one fungus develops in the host immunity from another.

The rust *Puccinia mamillata* while common upon the ordinary plants of the climbing smartweed (*Polygonum dumetorum*) was nearly absent from all infested with *Ustilago anomala.* It would seem that the smut had taken possession of the plant and the latter did not longer furnish the proper feeding ground for the rust. The same thing was found to be true with smutted specimens of *Panicum sanguinale*, the leaves of which are rarely affected with *Piricularia grisea*, while the normal plants have foliage spotted with it.

Transplanting. Burchard[61] calls attention to the fact that the American clover when grown in Europe, in spite of its more hairy character *is more subject to mildew than* the home grown varieties.

Soil Conditions as Affected by Manures. Emil Laurent[62] found that the same variety of potato on which different fertilizers had been used showed different conditions for bacteriosis. Nitrogenous and potash manures made the potatoes more immune toward *Bacillus coli communis* of artificial infection. The author thinks that the ability of a potato to resist bacteriosis rests upon the ability of the cells to produce soluble cell substances whose strength is utilized by alkaline conditions.

Toxin. Miss C. E. Marryat[63] states that a very susceptible variety of wheat was cultivated to study the effect of immunity the germ tube entering readily by means of passing through the stomata. In the case of a resistant Einkorn the germ entering through the stomata but in a short time the hyphæ began to break up. The author suggests that immunity is due to the production of a certain toxin or antitoxin.

BIOLOGIC SPECIES.

Biological experiment with fungi is of great importance and considerable work has been done of recent years with the biologic species of rust and mildews.

[58]Waite. Report U. S. Dept. Agr. 1895:299.
[59]Pammel, Cedar Apple Fungi and Apple Rust. Bull. Iowa Agr. Exp. Sta. 84:36.
[60]Mycological Notes IV. Bull. Torr. Bot. Club. *26*:12-20.
[61]Landw. Wochen. bl. f. Schleswig Holstein 51:34.
[62]Ann. De l'Inst. Pasteur *13*:1. Centralb. f. Bakt. u. Par. 2 Abst. *5*:685.
[63]Jour. Agri. Sci. 2:129.

During the summer of 1908 there were placed under observation in the greenhouse, plants of the following grasses: *Lolium perenne, Phleum pratense, Poa pratensis, Agropyron repens, Panicum crus-galli, Bromus secalinus, Setaria glauca, Dactylis glomerata,* and *Hordeum jubatum.* Wheat plants bearing abundance of *Erysiphe graminis* were placed in contact with the leaves of these plants, none of which became affected by it.

From the work of Salmon[64] it appears that different forms of *Sphaerotheca humuli* occur upon Pyrus Aria, Potentilla, and other hosts, these forms having individual characteristics. "While these forms present slight morphological differences, these are not sufficiently marked to prevent the forms being considered as belonging to the species."

Dr. Salmon[65] experimented with mildew of *Erysiphe graminis.* The form found on wheat will not normally infect rye; but when the leaves of rye were injured by cutting or bruising they could be infected by the fungus from the wheat.

Dr. G. M. Reed who has carried on a series of experiments with Erysiphe *cichoracearum*[66] D. C. has shown quite conclusively that the fungus "occurs on at least eleven species of the cucurbits belonging to seven genera, infection occurring in these cases in fifty per cent or more of the trials. Only three species belonging to two genera are entirely resistant to the mildew." It is evident also that this fungus will produce the mildew upon other forms of plants. In the record by Dr. Reed out of fifty-four leaves of common plantain inoculated with *Erysiphe cichoracearum* from squashes ten were affected.

The sunflower was likewise infected in 35 per cent of the trials, but he failed to inoculate mildew of cucurbits on asters and goldenrod.

Mr. Griffiths[67] observes that while the favorite habitat of *E. cichoracearum* appears to be on the composites, it is not confined to this group. The entire absence of the fungus on hosts which are generically related, is therefore a matter of surprise. Mr. Griffith observed such a case in a garden where three species of Artemisia, *A. Ludoviciana, A. tridentata, A. longifolia,* grew in profusion, and in closest proximity. *A. Ludoviciana* was loaded with *E. cichoracearum,* but search failed to find it upon the other two species. No positive reason can be given for the absence of this fungus on the two species in question, under such favorable conditions.

Although closely related there is much difference in the aromatic principle and the development of trichomes in the two species.

A parallel case was observed at Buffalo, Wyoming, where *A. dracunculoides* and *A. Canadensis* were grown together. The former had an abundance of *E. chichoracearum* upon it while the latter was entirely free.

Rusts also show peculiar relation to hosts. The *Puccinia coronata* does not grow equally well on the orchard grass, and on some other hosts on which it has been recorded. The forms of *Puccinia rubigo-vero* behave differently on various host plants. The form on rye is different than on wheat.

J. Ericksson[68] who has made a special investigation of cereal rusts considers that the several forms of *Puccinia graminis* on different host plants are distinct.

[64]Monograph of the Erysiphaceae. 56.

[65]Annals of Bot. 19:125.

[66]Reed, G. M. Infection experiments with *Erysiphe cichoracearum* D. C. Separate Bull. U. Wis. 250:341.

[67]Griffiths. Some Northwestern Erysiphaceae. Bull. Torr. Bot. Club 26:138-144.

[68]Ueber die Spezialsierung des Getreidesschwarzrostes in Schweden und in anderen Landern. Centralb. f. Bakt., Abt. 2.9:590-607, 654-658. 1902.

e. g., P. graminis secals on rye, *P. graminis tritici* on wheat, *P. graminis* on Poa.

Klebahn[69] too has found that some of our rusts must be considered as biologic forms. Demonstrated especially in connection with the aecidial forms of the grass and grain rusts.

Carleton[70] arrived at somewhat similar conclusions.

Arthur[71] also reports on the restrictive development of some of the species. Freeman's[72] work clearly indicates as quoted by Reed that the uredospores of barley will infect wheat and rye as well as barley and oats. The uredospores from rye will infect rye, wheat, barley, but not oats.

The following record is a summary of the work conducted by this Station since 1892, and the previous work by Dr. Halsted and Dr. Bessey. We have therefore a record of the abundance of fungus diseases in Iowa for nearly twenty-five years. The earlier records, of course, are not so complete as the later records. For use of characters see end of table.

Eriksson and Henning Die Getriederoste. Stockholm. 1896.

[69]Die wirtswechselnden Rostpilze. Berlin. 1904.

[70]Cereal Rusts of the U. S. Bull. Bur. Pl. Ind. Veg. Phys. and Path. U. S. Dept. Agrl. 16.

[71]Cultures of Uredineae 1904. Jour. Myc. *11*:50.

[72]Cited by Reed 66.

COMPARATIVE DISTRIBUTION OF COMMON FUNGUS DISEASES IN

Name of Disease	1870-1877	1878-1881	1882	1883	1884	1885
Bacteriaceae—						
1 Apple and pear blight	+	+				
2 Sorghum blight						
3 Potato wilt						
4 Turnip rot and cabbage rot						
5 Bacteriosis of corn						
6 Carrot rot						
7 Bacteriosis of potato						
Peronosporeae—						
8 Potato rot, early blight	0	0				(?) —
9 Downy mildew of grape				—	(*a*) —	
10 Downy mildew of Shepherd's Purse						
11 Downy mildew of lettuce				—	—	
12 Millet disease						
13 White rust of radish and Shepherd's Purse	+	+				
Exoasceae—						
14 Plum pocket		+		—	—	
15 Enlarged plum branches						
16 Peach curl		—		—	—	
17 Cottonwood curl						
Erysipheae—						
18 Rose mildew						
19 Mildew of apple						
20 Powdery mildew of cherry	—	+	—	—	—	
21 Powdery mildew of grape	+	'80 —	'83 —	—	—	
22 Powdery mildew of Dooryard Knotgrass						
23 Powdery mildew of Lilac	+	—	—	—	—	
24 Powdery mildew of pea	+	—	—	—	—	
25 Powdery mildew of grass						

IOWA, FOR THE PERIOD 1870 TO 1908 INCLUSIVE.

1886	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908
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COMPARATIVE DISTRIBUTION OF COMMON DISEASES IN

Name of Disease	1870–1877	1878–1881	1882	1883	1884	1885
Hypocreaceae—						
26 Ergot	—				—	—
Fungi Imperfecti, etc.—						
27 Spot disease of strawberry	+	+				
28 Apple-scab	0	—				
29 Black-Knot of plum	+		—	—		
30 Black-rot of grape						
31 Spot disease of walnut						
32 Potato-scab	—	—				
33 Potato blight (late)						
34 Spot disease of cherry	0	0				
35 Spot disease of black currant						
36 Spot disease of red currant						
37 Spot disease of gooseberry						
38 Spot disease of beet						
39 Anthracnose of raspberry	+					
40 Anthracnose of blackberry						
41 Spot disease of Alfalfa						
42 Brown-rot of stone fruits	0	0				
43 Wheat scab						
44 Wheat blight						
45 Bird's-eye fungus						
46 Brown-rot of Sugar Beet	0	0				
47 Scab on cherry						
48 Scab on plum						
49 Scab on peach						
50 Yellow leaf disease of barley						
51 Oak-spot						
Uredineae—						
52 Common grass rust	+	+	—	—		
53 Covered rust					—	
54 Crowned rust on oats			—	—	—	
55 Bean rust						

IOWA FOR THE PERIOD 1870 TO 1908 INCLUSIVE—CONTINUED.

1886	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908
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	−				−	−	+	−	−	−	−	−	−	−	−	−	−	(a) −	+	−	−	−
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						+		+	(?) +						+				−	−	−	+
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COMPARATIVE DISTRIBUTION OF COMMON FUNGUS DISEASES IN

Name of Disease	1870–1877	1878–1881	1882	1883	1884	1885
56 Clover rust						
57 Corn rust	—	—	—	—	—	
58 Plum rust						
59 Peach rust						
60 Cedar-apple rust	—	+			+	+
61 Cedar-apple rust						
62 Cedar apple rust						
63 Apple rust					+	+
64 Rust on Barberry						
65 Rust on ash	+	+				+
66 Red rust of raspberry						
67 Orange rust of rose						
68 Gooseberry rust	+					
69 Asparagus rust						
Ustilagineae—						
70 Oat smut						
71 Wheat smut (loose)						
72 Corn smut	+	—				
73 Barley smut						
74 Barley smut (naked)						
75 Bunt of wheat	—					
76 Foxtail smut						
77 Sorghum smut						
78 Timothy smut						
79 Crab-grass smut						
80 Wild rye smut						
81 Millet smut						

References:
(*a*) Abundant early in the season.
(*b*) Abundant early in season on cherry.
(*c*) Abundant in the fall.
(*d*) Abundant on seedlings.
(*e*) Common on sugar beet.
(*f*) Common on pepper-grass early in the spring.
(*g*) Abundant on seedlings of cherry and American plum.
(*h*) Abundant on wild apples.
(*i*) Severe locally.

IOWA, FOR THE PERIOD 1870 TO 1908 INCLUSIVE—CONTINUED.

1886	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908
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				—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
																						+

SCIENTIFIC NAMES OF FUNGIS DISEASES.

1. Bacillus amylovorus (Burr) De Toni.
2. Bacillus sorghi Burr.
3. Bacillus solanacearum Er. F. Sm.
4. Bacterium campestre (Pam.) E. F. Sm.
5. Bacillus cloacea Jordan
6. Bacillus carotivorus Jones.
7. Septoria ribis Desm.
8. Phytophthora infestans De By.
9. Plasmopara viticola (B. & C.) Berl and De Toni.
10. Peronospora parasitica (Pers.) De By.
11. Bremia Lactucae Regel.
12. Sclerospora graminicola Sacc.
13. Cystopus candidus (Pers.) Lev.
14. Exoascus pruni Fuck.
15. Exoascus communis Sad.
16. Exoascus deformans (Berk.) Fuckl.
17. Taphrina aurea (Pers.)
18. Sphaerotheca pannosa (Wall.) Lev.
19. Sphaerotheca Mali (De By.) Burr.
20. Podosphaera oxycanthae (D. C.) De By.
21. Uncinula necator (Schw.) Burr.
22. Erysiphe communis D. C.
23. Microsphaera alni (Wallr.) Schw.
24. Erysiphe communis D. C.
25. Erysiphe graminis D. C.
26. Claviceps purpurea (Fries.)
27. Sphaerella Fragariae (Tul.) Sacc.
27. Sphaerella Fragariae (Tul.) Sacc.
28. Venturia inaequalis (Cke.) Aderh.
29. Plowrightia morbosa (Schw.) Sacc.
30. Guignardia Bidwellii (Ell.) V. and R.
31. Marsonia Juglandis (Lib.) Sacc.
32. Oospora scabies Thax.
33. Macrosporium solani Ell and Mart.
34. Cylindrosporium Padi Karst.
35. Septoria ribis Desm.
36. Cercospora angulata Wint.
37. Septoria ribis Desm.
38. Cercospora beticola Sacc.
39. Gloeosporium venetum Speg.
40. Septoria Rubi Westd.
41. Pseudopeziza Medicaginis Sacc.
42. Sclerotinia fructigena (Pers.) Schw.
43. Fusarium culmorum (W. G. Sm.) Sacc.
44. Cladosporium herbarum (Pers.) Link.
45. Sphaceloma ampelinum De By.
46. Rhizoctonia betae Kuhn
47. Cladosporium carpophilum Thum
48. Cladosporium carpophilum Thum
49. Cladosporium carpophilum Thum
50. Helminthosporium graminum Rabh.
51. Marsonia Martini Sacc. and Ell.
52. Puccinia graminis Pers.
53. Puccinia rubigo-vera (D. C.) Wint.
54. Puccinia coronata Cda.
55. Uromyces appendiculatus (Pers.) Sacc.
56. Uromyces Trifolii (A. and S.) Wint.
57. Puccinia Sorghi Schw.
58. Puccinia pruni Pers.

59. Puccinia pruni Pers.
60. Gymnosporangium macropus L. R.
61. Gymnosporangium clavipes Cooke and Peck.
62. Gymnosporangium globosum Farl.
63. Roestelia pirata Thaxter.
64. Accidium Berberidis Gmel.
65. Accidium Fraxini S.
66. Gymnoconia interstitialis (Schl.) Lagh.
67. Phragmidium subcorticum (Schrnk.) Wint.
68. Aecidium Grossulariæ D. C.
69. Puccinia Asparagi D. C.
70. Ustilago avenae (Pers.) Jens.
71. Ustilago Tritici (Pers.) Jens.
72. Ustilago Zeae (Beckm.) Unger.
76. Ustilago neglecta Niessl.
74. Ustilago nuda (Jens.) Kell. and Sw.
75. Tiletia foetens (B. and C.) Tul.
76. Ustilago neglecta Niessl.
77. Sphacelotheca Reiliana (Kuhn) Clint. Sph. Sorghi (Lk.) Clint.
78. Ustilago striæformis (West) Neissel.
79. Ustilago syntherismæ Pk.
80. Urocystis agropyri (Preuss.)
81. Ustilago Crameri Korn.

AMES, TEMPERATURE IN DEGREES, AND PRECIPITATION IN INCHES, FOR YEARS 1907 AND 1901—A COMPARISON OF A DRY YEAR WITH A WET YEAR.

Month	1907				1901	
	Temperature in degrees			Precipitation in inches	Average tempsrature in degrees	Precipitation in inches
	Max.	Mean	Min.			
January	28.	19.	10.	.73	23.6	.57
February	36.	25.7	15.	.55	18.	.9
March	51.5	40.7	42.7	.27	34.4	1.64
April	54.2	42.	29.8	.67	49.	1.82
May	67.	53.4	40.	3.54	61.4	3.69
June	77.	64.9	52.	3.26	74.4	2.36
July	76.	69.3	55.	5.32	83.3	2.26
August	85.	66.5	48.	6.15	72.8	1.21
September	74.	62.4	50.6	2.14	61.	3.65
October	62.8	49.8	36.6	3.04	53.9	2.98
November	43.6	36.	25.	1.02	37.9	.67
December	38.	29.	19.	.83	20.5	.57
Totals	56.9	46.5	41.8	27.58	49.2	22.32

TEMPERATURE AND RAINFALL FOR AMES, 1908.

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oc.	Nov.	Dec.
Precipitation	.55	1.55	.45	1.94	7.95	3.93	3.63	5.9	.5	6.23	------	------
Temperature	24.8	24.8	38.1	50.4	59.3	67.	72.8	69.	66.1	52.4	------	------

AMES, MEAN TEMPERATURE IN DEGREES, 1876-1907.

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Mean
1876	16.	30.	26.	48.	61.	68.	75.	74.	71.	46.	29.	11.	45.5
1877	12.	33.	26.	48.	61.	68.	75.	72.	64.	49.	20.	17.	45.3
1878	23.	24.	45.	52.	56.	68.	78.	75.	62.	48.	39.	16.	48.9
1879	14.	21.	37.	50.	63.	70.	78.	72.	60.	58.	34.	16.	47.7
1880	32.	30.	------	46.	69.	73.	77.	75.	61.	47.	24.	15.	------
1881	8.	16.	27.	43.	69.	72.	79.	77.	66.	53.	33.	31.	47.8
1882	22.	32.	35.	50.	54.	70.	72.	73.	65.	54.	36.	19.	48.5
1883	3.	14.	29.	51.	55.	68.	76.	70.	------	44.	------	------	------
1884*	15.9	19.1	35.3	53.2	65.3	76.9	78.1	74.5	72.7	59.5	40.1	17.6	42.35
1885*	10.5	12.5	34.7	51.3	64.2	68.1	79.8	74.3	67.7	54.7	43.	29.3	49.3
1886*	11.4	25.	37.3	58.	69.9	78.7	86.4	85.	70.9	63.	37.7	17.9	45.1
1887*	13.	21.2	38.9	60.	73.5	82.3	87.3	80.3	67.3	59.1	40.9	23.9	53.9
1888	------	20.	23.	49.	43.	68.	75.	70.	80.	47.	------	28.	------
1889	21.	18.	39.	50.	60.	67.	73.	71.	61.	47.	32.	37.	48.
1890	18.	25.	28.	54.	58.	73.	77.	68.	60.	49.	------	------	------
1891	25.	19.	28.	51.	59.	69.	70.	69.	68.	48.	30.	32.	47.3
1892	16.	------	------	46.	52.	69.	74.	72.	64.	54.	33.	15.	------
1893	6.	18.	31.	44.	54.	73.	79.	72.	68.	55.	36.	22.	46.6
1894	16.	17.	39.	50.	60.	72.	------	------	65.	51.	31.	29.	------
1895	12.	16.	34.	54.	61.	68.	70.	72.	68.	49.	32.	25.	46.8
1896	------	------	------	------	65.	70.	72.	------	56.	47.	30.	31.	------
1897	17.	25.	32.	48.	59.	69.	78.	70.	72.	56.	34.	15.	47.9
1898	23.	23.	38.	49.	60.	71.	73.	72.	65.	47.	37.	10.	47.3
1899	20.1	18.2	25.	48.6	60.5	70.7	73.2	74.2	62.8	57.2	44.1	21.1	48.
1900	26.4	------	------	------	64.4	69.4	73.	76.8	66.	59.8	33.	27.2	------
1901	23.6	18.	34.4	49.	61.4	74.4	83.3	72.8	61.	53.9	37.9	20.5	49.2
1902	21.8	15.3	40.1	48.6	64.2	65.6	72.8	69.3	59.8	52.8	40.8	20.6	47.6
1903	24.	19.6	38.4	49.8	62.3	64.8	73.4	69.4	60.5	51.6	35.2	20.2	47.4
1904	14.	14.9	35.	45.	60.	67.4	70.2	69.	64.5	53.6	41.3	22.2	46.4
1905	14.5	13.5	44.	47.4	58.4	70.4	70.4	75.4	65.7	49.4	38.2	28.2	48.
1906	24.8	24.3	27.4	52.7	60.8	68.1	70.6	73.8	66.8	51.	35.7	27.	48.6
1907	19.	25.7	40.7	42.	53.4	64.9	69.8	66.5	62.4	49.8	36.	29.	46.6
Average	15.	22.2	33.9	49.6	62.4	70.2	75.4	72.8	65.1	52.	35.1	27.1	47.4

*Noon readings—not averaged into total.

AMES, PRECIPITATION IN INCHES, 1876-1907.

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Annual Sum.
1876	1.9	.4	2.35	1.50	4.25	4.28	6.50	8.29	5.14	.75	1.72	.02	37.10
1877	.45	------	1.41	1.96	4.43	7.94	3.60	6.48	.90	3.14	.69	------	------
1878	------	------	4.09	3.39	4.35	7.53	5.33	1.95	3.00	1.38	.35	.83	------
1879	.43	1.08	.78	1.27	4.46	4.65	.48	3.98	2.62	3.34	5.75	.25	29.12
1880	1.25	.52	------	2.66	3.06	2.37	4.18	6.02	6.34	1.18	1.20	.84	------
1881	.68	2.50	.94	2.37	2.32	6.70	16.31	3.25	7.63	6.24	2.7	.89	51.9
1882	.57	1.14	3.09	2.44	5.21	7.43	2.66	2.15	.51	3.37	2.17	.98	31.72
1883	1.24	1.39	.32	3.55	7.11	3.52	6.30	2.92	1.67	2.80	------	------	------
1884	.31	1.12	1.79	3.30	1.80	2.06	4.71	2.50	5.68	4.02	.85	1.86	30.00
1885	.23	.34	.24	3.76	3.69	6.01	4.31	9.40	3.64	2.06	.25	.88	33.41
1886	3.57	.22	.98	3.05	2.78	1.87	.06	.53	4.66	1.11	1.12	.66	20.61
1887	.63	1.44	.66	1.28	.39	1.81	2.78	1.73	9.77	1.50	.43	.90	22.76
1888	1.08	1.30	2.86	2.25	6.49	3.65	5.15	3.37	.85	1.45	------	1.90	------
1889	1.80	.48	T	2.21	4.18	4.90	4.10	.87	2.47	.40	1.15	.95	23.51
1890	1.95	.96	1.20	2.10	4.62	5.65	1.85	4.55	3.20	2.38	.10	.85	29.40
1891	2.25	1.20	2.55	1.85	2.25	4.92	3.87	3.35	1.05	2.78	1.95	2.40	30.22
1892	1.00	.30	2.30	4.28	8.86	3.74	7.06	1.95	.16	1.79	.63	.92	32.99
1893	.28	1.37	1.73	2.42	4.89	4.70	2.47	1.08	1.86	.52	.62	1.05	22.99
1894	1.06	1.00	1.51	4.25	.87	3.51	.04	2.10	3.84	4.71	.45	.61	23.95
1895	.09	.53	.60	4.08	4.28	4.69	2.70	4.93	3.93	.47	1.09	1.56	28.95
1896	.44	.25	1.12	4.29	6.18	2.06	9.96	2.24	4.10	2.44	1.21	.37	34.66
1897	1.29	.22	.29	5.70	2.58	2.16	2.45	1.48	3.24	1.63	.49	1.56	23.09
1898	.46	1.42	.78	1.52	3.88	7.10	1.10	3.30	3.07	6.03	1.40	.54	29.60
1899	.11	.30	.49	2.01	7.23	6.45	1.60	3.70	.89	2.03	1.25	2.35	28.99
1900	.38	.45	2.81	2.61	4.36	6.48	9.14	5.46	7.12	3.73	.51	.19	43.24
1901	.57	.90	1.64	1.82	3.69	2.36	2.26	1.21	3.65	2.98	.67	.57	22.32
1902	1.32	.38	2.70	2.35	6.69	10.01	8.06	7.12	1.66	2.56	1.11	1.87	45.97
1903	.28	1.47	1.44	2.39	7.30	1.33	2.47	7.31	4.43	2.15	.60	.50	31.97
1904	.50	.40	1.63	4.19	3.69	3.45	2.39	3.37	3.37	1.78	.02	.79	25.58
1905	.64	.67	2.30	1.33	5.51	4.23	2.14	3.03	2.96	3.55	2.43	.23	29.02
1906	1.12	.28	.58	3.16	1.73	3.71	4.06	5.28	3.14	1.72	1.74	.70	27.22
1907	.79	.55	.27	.67	3.54	3.26	5.32	6.15	2.14	3.04	1.02	.83	27.58
Average	.93	.8	1.51	2.69	4.27	4.36	4.16	6.58	3.39	2.47	1.04	.96	30.22

COMPARATIVE DISTRIBUTION FOR THE UNITED STATES OF COMMON

	1900	1901	1902
1 Apple and pear blight		+Alleghany region —Iowa and central	+Ohio to N. Dakota
2 Black-rot of cabbage		+Mass. to Ohio +Southern Texas	—Northern states +Texas —Iowa
3 Potato-rot	—Atlantic coast states +Pacific Coast		+N. Eng. to Mich. Absent in Iowa, Cal. and northwest
4 Downy mildew of grape			+Iowa
5 Peach curl		+Eastward	+Iowa +Eastward
6 Plum pocket			

FUNGUS DISEASES FOR THE PERIOD 1900 TO 1907 INCLUSIVE

1903	1904	1905	1906	1907
+East +Colorado +New Mexico +Iowa	+General +Southern states +Iowa +Pacific Coast	+General +Ala., Tenn., Pa., O., Mo., Ia., Minn., Neb., Utah	+Del., N. J., Md., N. Y., Tenn., Ky., Wy., Col., Ark., U., Sacramento Val.	+N. J., Md., N. Carolina +N. Dak., Nev.
Uncommon	—Eastern, central and southern states +Iowa	+O., Ind., Gulf States —Iowa	+general, Del. to Neb., Kan., Mo. to S. Car. +Iowa	+Del., Ind., to Nebraska +Minn. to Texas +Vermont +Arizona
+Kan., Ia., Mo. to Va. and Fla. +Pacific Coast —Southern states	—New England (tubers +) +Ohio —Mich., Wis., Fla., Minn. 0 Iowa	+Me. to Minn. 0 Iowa	+Fla., N. Y. +Long Island +Vermont	+Texas, Va., Col., Md., N. Y., Ver., Me.
+Eastern states +Iowa	+N. Y., Pa. —Iowa, Minn. —Wis., Ind.	+Ark., N. Y. —Conn., O., to Wis. +Iowa	—N. H., Md. to Neb., Ken., Missouri +Iowa	+Ky., Georgia —Ver., Ohio —Iowa —Mass., Md., W. Va., La., Delaware
+Iowa +Eastward	+Eastward	+N. Y., Pa., O. —Eastern and middle states	—Ala., W. V., N. Y., Ind., Neb., Wash., +Ga., Iowa and N. Jersey	+California +N. J., R. I., O., N. York —Del., Ga., N. H., Ind., Ia., Idaho, Mass.
—Iowa	—Iowa	—Iowa	—General	+Ohio —Iowa, Neb. —Rhode Island, Vermont

COMPARATIVE DISTRIBUTION FOR THE UNITED STATES OF COMMON

	1900	1901	1902
7 Black-rot of grape	+Eastward N. Y. to Gulf states —Iowa	+Md. to North Car. —Country at large	+R. I. to W. V. and Ohio
8 Bitter-rot apple			—Va., Maryland +W. V., O., Ill., Mo. —Iowa
9 Apple scab	+Eastward —Iowa	+Central and eastern states +California —Iowa	+Maine to Iowa
10 Early blight of potato		+Md., Ark. +Iowa	
11 Shot hole fungus of cherry		—Country at large	+Iowa
12 Spot disease of currant and gooseberry			+Iowa and Neb.
13 Spot disease of beet		+Texas, N. Mexico, Iowa	

FUNGUS DISEASES FOR THE PERIOD 1900 TO 1907 INCLUSIVE—CONTINUED.

1903	1904	1905	1906	1907
+R. I. to N. Y.	+Maryland —W. Va. to Neb. —Iowa	+Iowa	0 Lake Erie region +Central N. Y., Michigan —Iowa	+Michigan +New Jersey +N. Carolina —N. Y., Mass., Md., Delaware
	—Southwest and general U. S. Mo., Ark. to Va.	+Md., Va., W. Va. —O., Ark., Mo.	—Va., N. C., Ky., S. Car., Missouri	—Mass. and R. I., southward —Ozarks
—N. Eng. and central states +Wis., Ia., Neb., Missouri —Mont., Idaho	+Eastern U. S. +Iowa —California	+Ark., Ind., Ia., Mich., Neb., Dakota —New York —Pacific Coast	—Eastern & central U. S. —Western states +Iowa	—N. York and Michigan +N. H., Maine —Md., W. Va., Virginia west to Arkansas +Iowa
	+Mass., N. Y.	—Mass., N. Y., N. Eng., Fla., Mich., Ia., Neb., Wis.	+Northern states N. Eng. to O. —South	+Northern states N. Y. to Wis.
+Iowa	+Maryland —W. V., Mo., Kansas 0 Neb., Iowa	+Neb., N. Y., W. V., O., Fla. —Iowa and Mo.	—O., Ind., Ia., Nebraska +N. Y., W. Va., Md., Mo.	+Washington, Ind., Neb. —Mass. to N. Car., Ky., Tenn., Del., O. Iowa
+Iowa		+Iowa, Neb., O. W. Virginia	—W. Va., O. and Iowa	—Md., Ky., R. I., N. J., Neb. Ohio, Iowa
—Not prevalent in eastern states				—Louisiana

COMPARATIVE DISTRIBUTION FOR THE UNITED STATES OF COMMON

	1900	1901	1902
14 Anthracnose of raspberry	—Neb. eastward	+N. Y to Minn. +Iowa	+Neb. and Mo. to N. York +Iowa
15 Spot disease of Alfalfa			+New York —Iowa
16 Brown rot of stone fruits	+Northern fruit belt —Pacific Coast	+N. Y. (cherries) +Conn. and south —Mich., Mo., Ill. +Iowa (plums)	—Cal., (absent on rest of coast) +Iowa +Northern fruit belt (absent on peaches)
17 Wheat scab			
18 Apple rust	+Locally, Nebraska eastward		
19 Bean rust			
20 Asparagus rust	+East and south to S. Carolina —S. Dakota, Iowa, Kansas		+N. Eng., O., and westward Iowa

FUNGUS DISEASES FOR THE PERIOD 1900 TO 1907 INCLUSIVE—CONTINUED.

1903	1904	1905	1906	1907
+N. Y. and central states +Iowa	+New York +Iowa	+Central, western +Iowa	+Iowa	+Md., Mo., Ky. O., Mich., N. Jersey +Wis., Ill.
+Ohio, S. Car. +Iowa	+New York +Iowa	+Central, Western +Iowa	+Iowa	—General
—Eastern states +Iowa +Southern states, Georgia	+Md. plum, northern and central states —Mich., Ga. —Iowa	+N. Y., N. J., Mo., O., W., Virginia —R. I., Neb., Mo., Iowa +Fla. to N. J., Ind., Mo., Neb. (on peach)	+Ga., Va., Md., Del., O., N. Y., Mo. and Arkansas —Iowa	+Okla., Ala., Md., Mo. +Georgia —Iowa —R. I., Neb., Ind., Ill., Tennessee
+Neb., Ia., Ohio	+Neb., Kan., Mo., Ohio	+Minnesota +N. Dakota —Iowa	—General +Sacramento Valley	+Ohio +Iowa +Ind., Neb.
—Iowa	+O., Neb., Iowa	+W. V. to Ga. +Iowa	—Locally +Iowa	—Del., Ky., N. J., N. Y., Iowa, Neb., N. Car., O,, W. V., Mass., Md.
+Wis., Neb., N. Car., W. Va.	+Ind., Neb., N. Car., W. V. 0 Iowa	—Wisconsin +Conn., O., W. Va., Ia., New Mexico	—Ind., N. J., Pa., Ky., O., Nebraska ------ +Colorado	—N. Car., La., Delaware +Iowa —N. J., Mass., Alabama
—Eastern and central +Neb., Iowa, California	+Eastern and central, N. D., Neb., and Iowa	+Eastern +Pacific slope —S. Car., O., Ia., Neb., N. Dakota	+Eastern states —S. Car., O., Ia., Neb., N. Dakota +Pacific slope	—General —Iowa +Conn., Ill., Col., Mo.

COMPARATIVE DISTRIBUTION FOR THE UNITED STATES OF COMMON

	1900	1901	1902
21 Red clover rust		+Iowa	+Iowa
22 Wheat rust	—Country at large	—Country	+N. D., Kan., Ill., Wis., Mo., Iowa
23 Oats rust	—Iowa	—Iowa	+N. D., Kan., Mo., Wis., Ill., Iowa
24 Barley rust			
25 Oat smut	—Country at large	—N. D. to Kan., Mo., Wis., Ill.	—Country at large
26 Wheat smut	—Country at large	—N. D., Kan., Mo., Wis., Illinois	—Country at large
27 Corn smut	—Country at large	—N. D., Kan., Mo., Wis., Illinois	—Country at large

FUNGUS DISEASES FOR THE PERIOD 1900 TO 1907 INCLUSIVE—CONTINUED.

1903	1904	1905	1906	1907
+New York +Michigan +Iowa	+Iowa	+General +Ia., Md., Tenn	—Ind., O., Md., W. Virginia —Iowa	—Neb., O., Md., Mo., Del., N. Y., N. J.
—Iowa	+Wis., O., Dakotas, Neb., Ia., Mo.	—Dakotas, Wis., Neb., Iowa, northeast +O., Md., Ind., W. Virginia	—Dakotas, Wis., Neb., Iowa, northeast +Minnesota	—General +Iowa
	+O., Ia., Neb., Minn., Dakotas —Ind., Mont.	—Iowa	—General	+Miss. Valley +Iowa
	—General		—General	—Minnesota +Iowa
+General	+General	—Vermont to Ia. and Wisconsin +N. C., Ohio	—General	+Wisconsin +Washington
+General	+General +Iowa		—General +Iowa	—General +New York +O., Texas, Wash., Kan.
+General	+General	+General	—General +Sacramento Val. and Cal.	—General +Iowa +Locally

1. Bacillus amylovorus (Burr.) De Toni.
2. Bacterium campestre (Pam.) Er. F. Sm.
3. Phytophthora infestans De. By.
4. Plasmopara viticola (B. and C.) Berl. and De Toni.
5. Exoascus deformans Berk.
6. Exoascus pruni Fuck.
7. Guignardia bidwelii (Ell.) V. and R.
8. Glomerella rufomaculans (Berk.)
9. Venturia inequalis (Cke.) Wint.
10. Macrosporium solani Ell. and Mart.
11. Cylindrosporium padi Karst.
12. Septoria ribis Desm.
13. Cercospora beticola Sacc.
14. Gloeosporium venetum Speg.
15. Pseudopeziza medicaginis Sacc.
16. Sclerotinia fructigena (Pers.) Schw.
17. Fusarium culmorum (W. G. Sm.) Sacc.
18. Roestelia pirata Thaxter.
19. Uromyces appendiculatus (Pers.) Sacc.
20. Puccinia asparagi D. C.
21. Uromyces trifolii (A. and S.) Wint.
22. Puccinia graminis Pers.
23. Puccinia rubigo-vera (D. C.) Wint.
24. Puccinia straminis var. simplex Koern.
25. Ustilago avenae (Pers.) Jens.
26. Ustilago tritici (Pers.) Jens.
27. Ustilago zeae (Beckm.) Unger.

AVERAGE TEMPERATURE FOR WISCONSIN, IN DEGREES.

	March	April	May	June	July	Aug.			Average
1884	26.9	43.3	57.8	68.2	68.7	67.1	65.4	52.4	56.2
Average for 28 years	30.1	44.5	57.6	67.3	72.4	69.6	61.1	48.8	56.4

PRECIPITATION FOR WISCONSIN IN INCHES.

	March	April	May	June	July	Aug.	Sept.	Oct.	Sum,
1884	2.31	4.51	4.21	5.41	8.44	4.3	4.25	4.6	38.
Average for 28 years	2.17	2.28	3.6	4.13	4.	3.2	3.21	2.4	24.9

AVERAGE TEMPERATURE FOR IOWA, IN DEGREES.

	March	April	May	June	July	Aug.	Sept.	Oct.	Average
Noon Readings—1884	35.3	53.2	65.3	76.9	78.1	74.5	72.7	59.5	64.7
Average for 31 years	33.9	49.6	62.4	70.2	75.4	72.8	65.1	52.	60.2

PRECIPITATION FOR IOWA, IN INCHES.

	March	April	May	June	July	Aug.	Sept.	Oct.	Sum.
1884	1.79	3.3	1.8	2.06	4.71	2.5	5.68	4.02	25.8
Average for 31 years	1.51	2.69	4.27	4.36	4.16	6.58	3.39	2.47	29.4

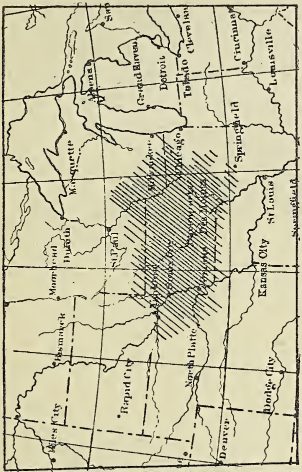
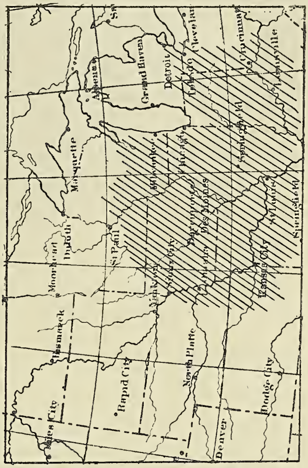



Fig. 3. Ash Rust. 1884.
Fig. 4. Apple Rust. 1884.

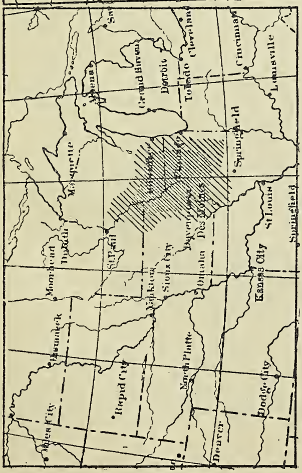
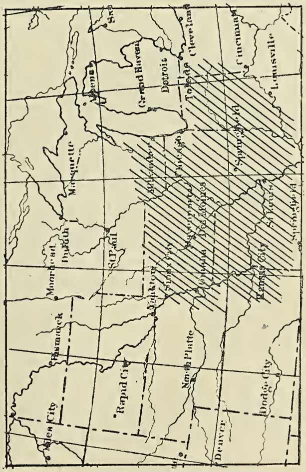
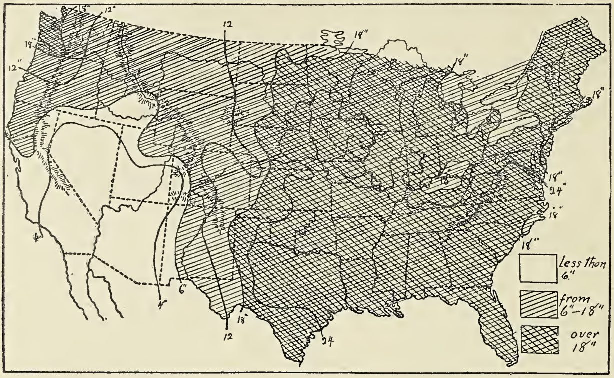
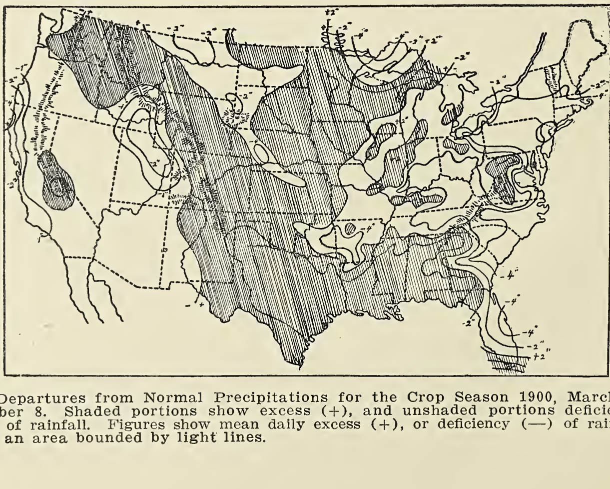



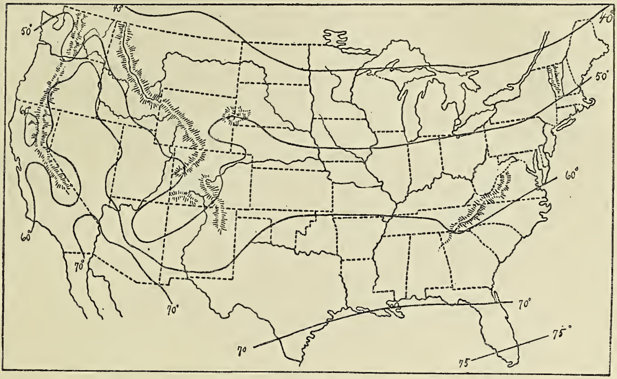
Fig. 1. Potato Rot. 1884.
Fig. 2. Powdery Mildew, Cherry. 1884.



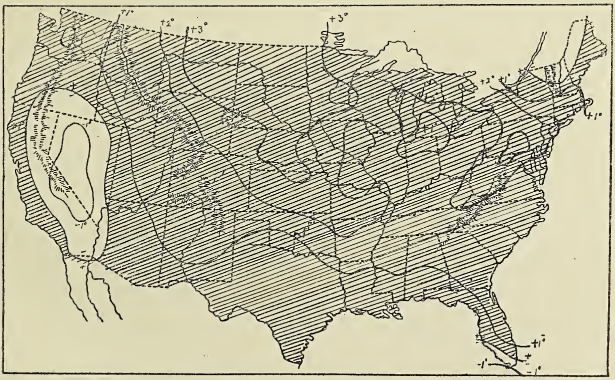
Total Precipitation for the Period March 1-October 8, 1900—222 days.



Departures from Normal Precipitations for the Crop Season 1900, March 1-October 8. Shaded portions show excess (+), and unshaded portions deficiency (—) of rainfall. Figures show mean daily excess (+), or deficiency (—) of rainfall over an area bounded by light lines.

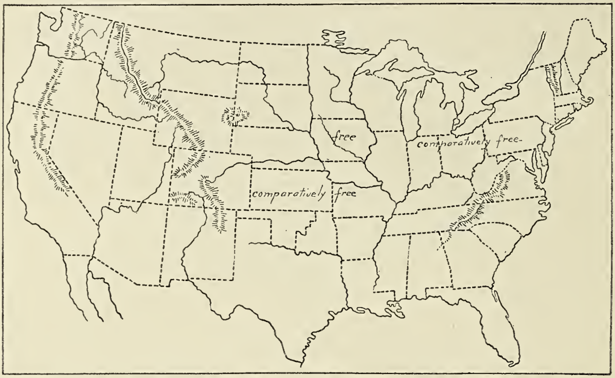


Mean Surface Temperature. **1900.**
Observations taken at 8 a. m. and 8 p. m., 75th meridian time.

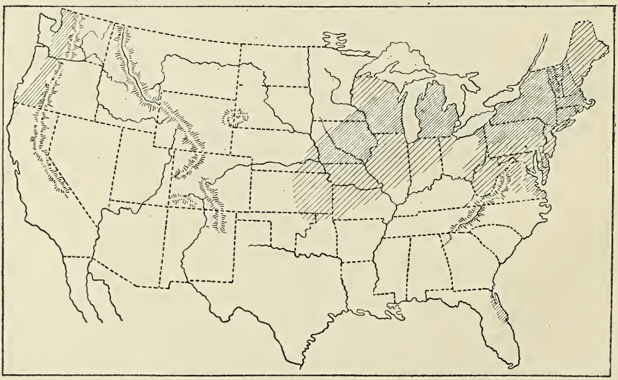


Average Daily Departure from Normal Temperature of Crop Season of 1900, March 1-October 8. Shaded portions show excess (+) and unshaded portions deficiency (—) of temperature. Figures show mean daily excess (+) or deficiency (−) over areas bounded by light lines.

Maps showing rainfall and temperatures for the years 1900 to 1907, for the United States.

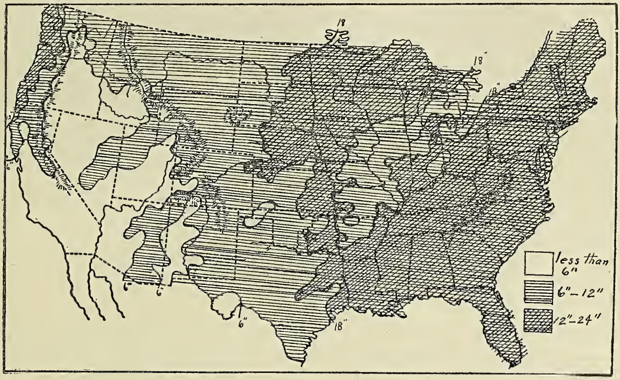


Wheat, Oats Rust, etc., 1901. Country as whole, free.

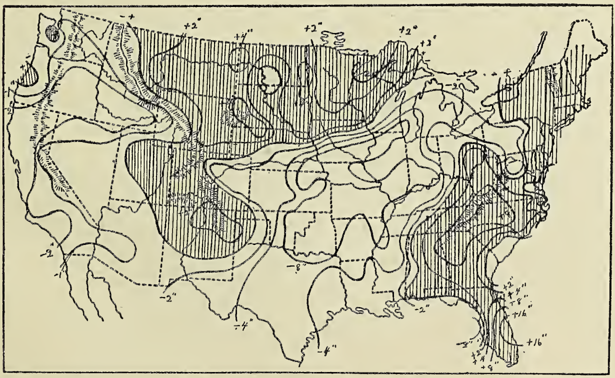


Wheat and Grain Rust. 1904.

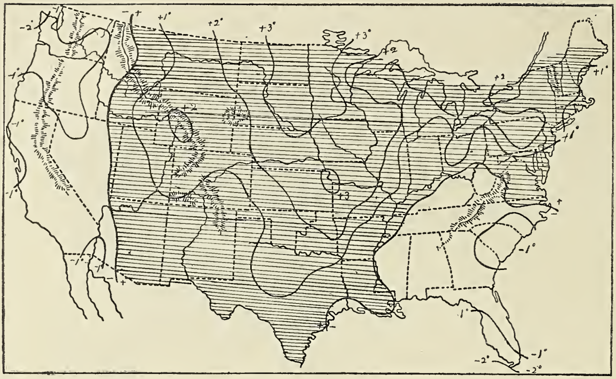
Maps showing distribution of Wheat and Grain rust for a favorable, and an unfavorable year. See accompanying United States maps for weather, 1901 and 1904.



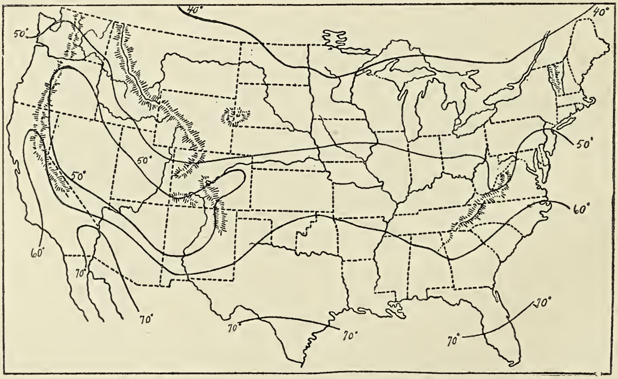
Total Precipitation for the Crop Season of 1901, March 1-September 30.



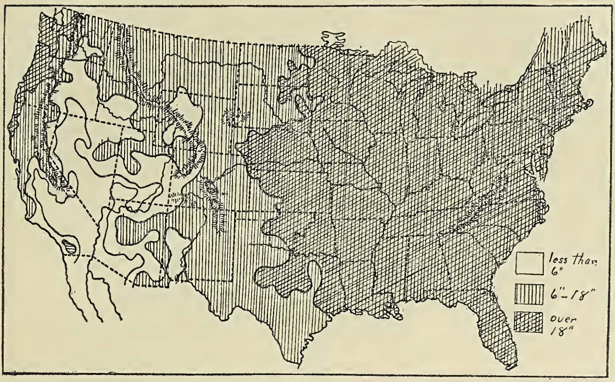
Departures from Normal Precipitation for the Crop Season of 1901, March 1-September 30. Shaded portions show excess (+), and unshaded portions deficiency (—) of rainfall over areas bounded by light lines.



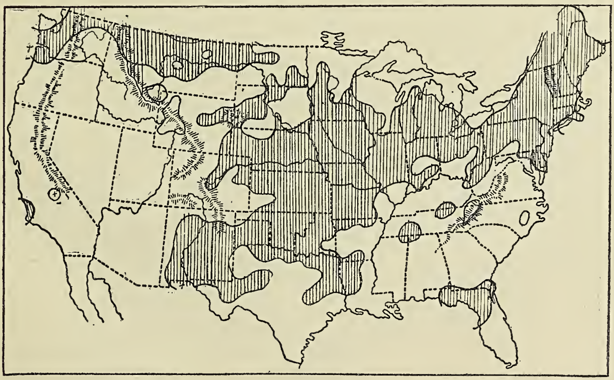
Average daily departures from Normal Temperature for Crop Season 1901, March 1-September 30. Shaded potions show excess (+), unshaded potions deficiency (—) of temperature. Figures show mean daily excess (+) or deficiency (—) of temperature over areas bounded by light lines.



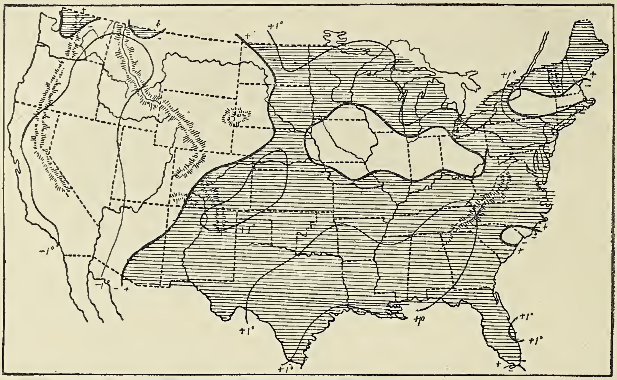
Mean Surface Temperatures for 1901.



Total Precipitation for the Crop Season of 1902, April 7-September 29.

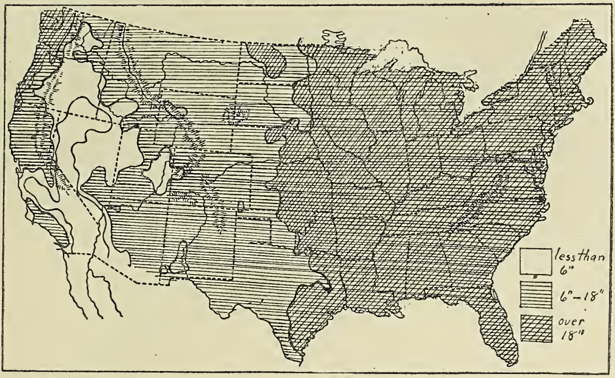


Departures from Normal Precipitation for Crop Season of 1902, April 7-September 29. Shaded portions show excess; unshaded portions deficiency.

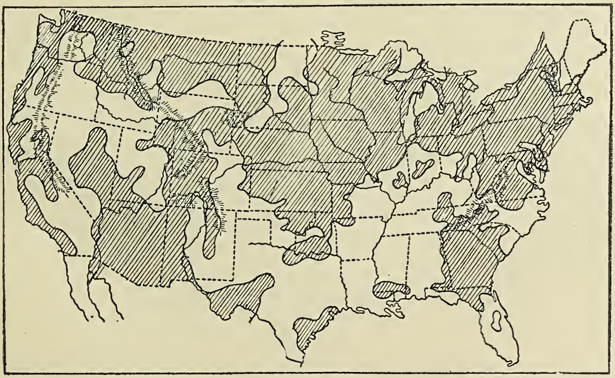


Average daily departures from Normal Temperature for Crop Season 1902, April 7-September 29. Shaded portions show excess (+), and unshaded portions deficiency (—) of temperature. Figures show mean daily excess (+) or deficiency (—) of temperature over areas bounded by light lines.

Mean Surface Temperatures. 1902.

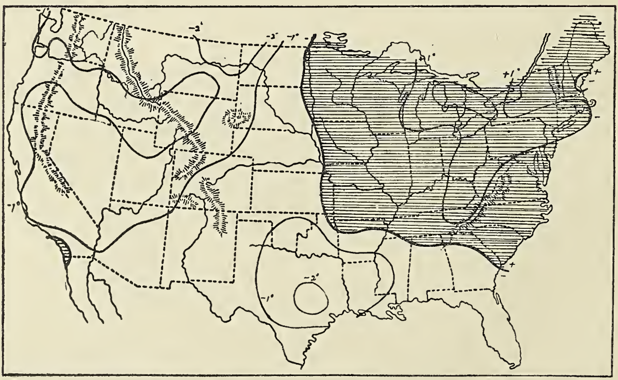


Total Precipitation for the Crop Season of 1903, March 1-October 5.

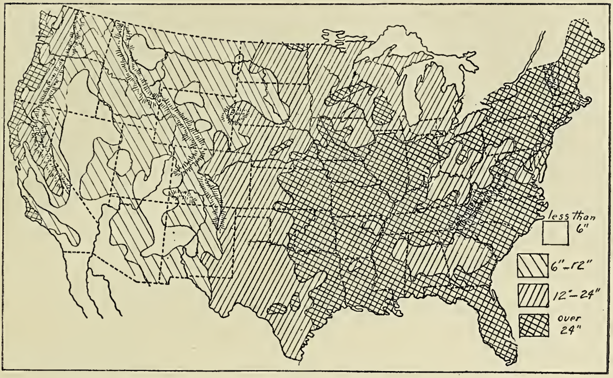


Departure from Normal Precipitation for the season of 1903, March 1-October 5.

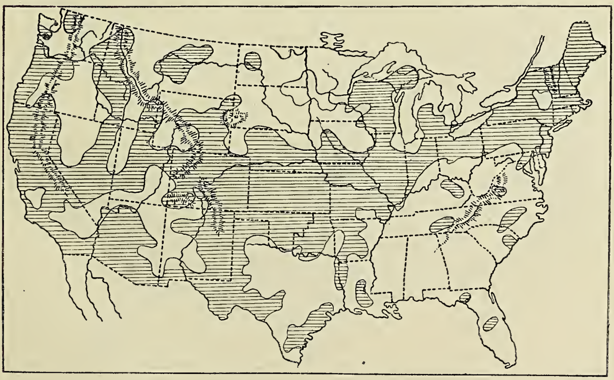
Mean Surface Temperatures for 1903.



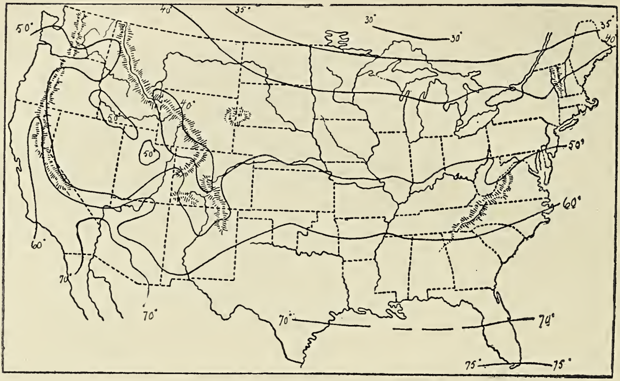
Average daily departures from Normal Temperature for the Crop Season of 1903.



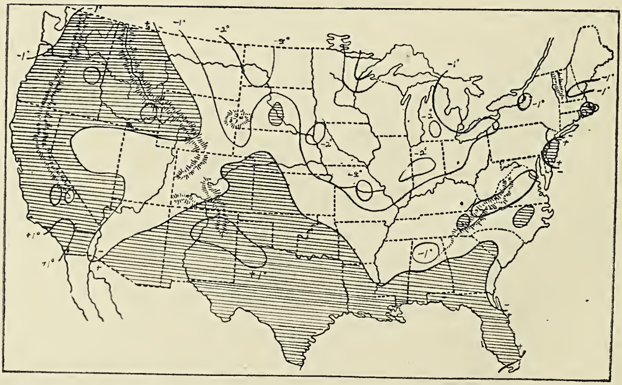
Total Precipitation, Crop Season 1904, March 1-October 3.



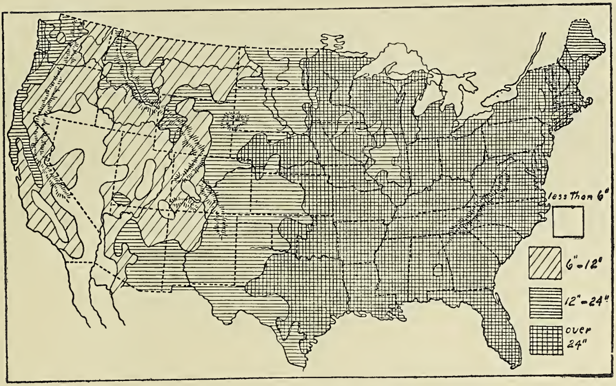
Departure from Normal Precipitation, 1904, March 1-October 3.



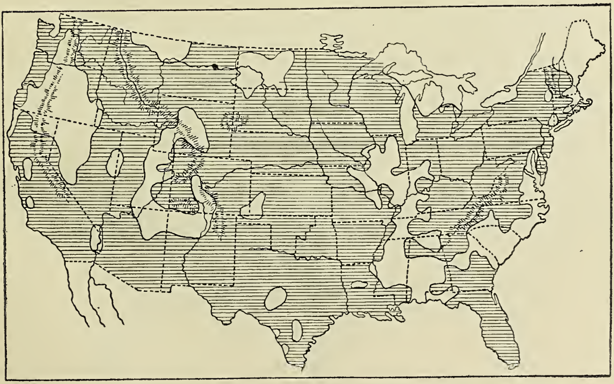
Mean Surface Temperature for 1904.



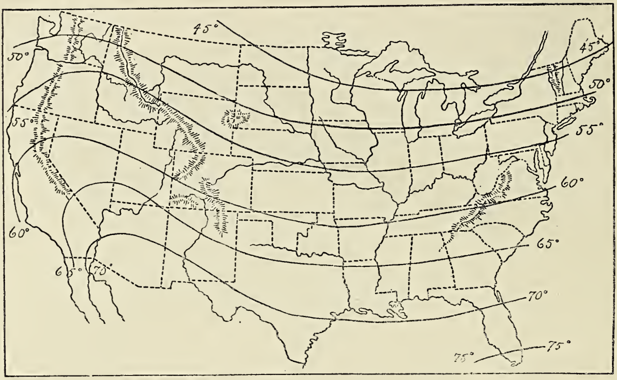
Departure from Normal Temperature for Crop Season of 1904, March 1-October 3.



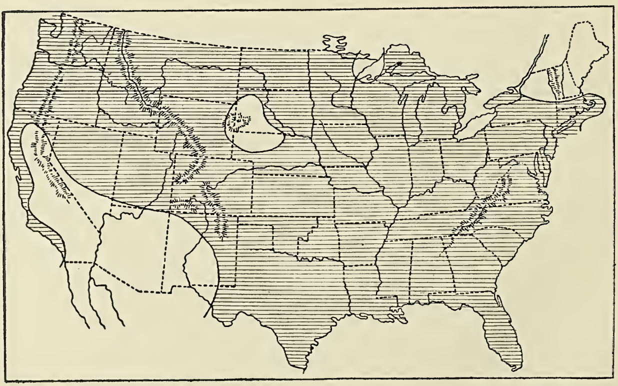
Total Precipitation 1905. Crop Season, March 1-October 3.



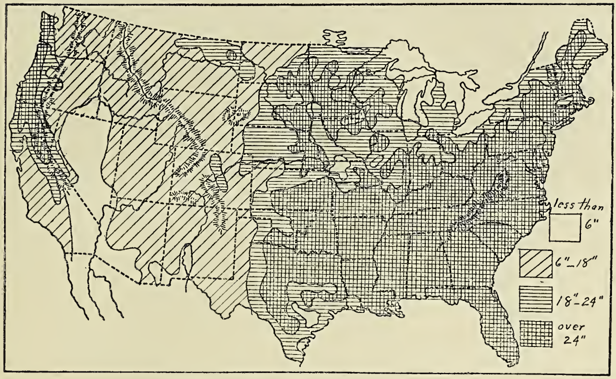
Departure from Normal Precipitation 1905. Shaded portions excess, unshaded portions deficiency. March 1-October 3.



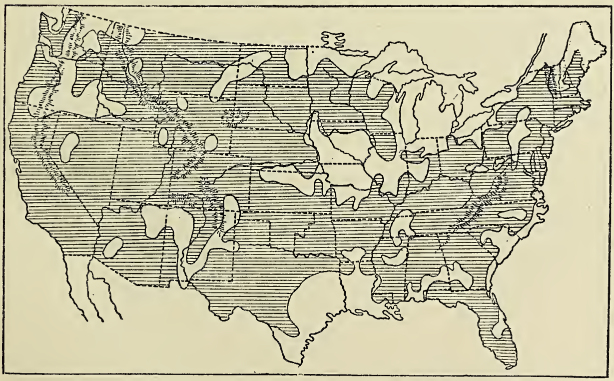
Mean Surface Temperature. 1905.



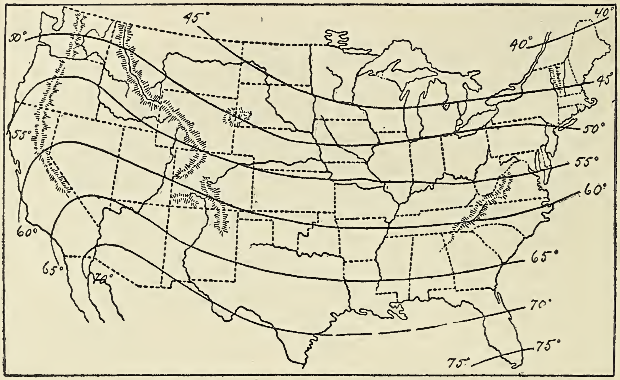
Departures from Normal Temperature 1905, March 1-October 3. Shaded portions excess, unshaded portions deficiency.



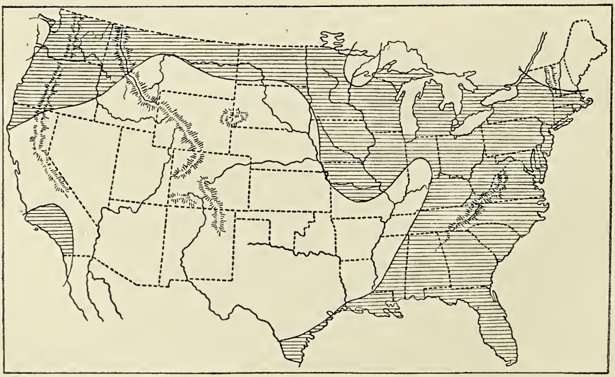
Total Precipitation 1906, March 1-October 3.



Departure from Normal Precipitation 1906, March 1-October 3.

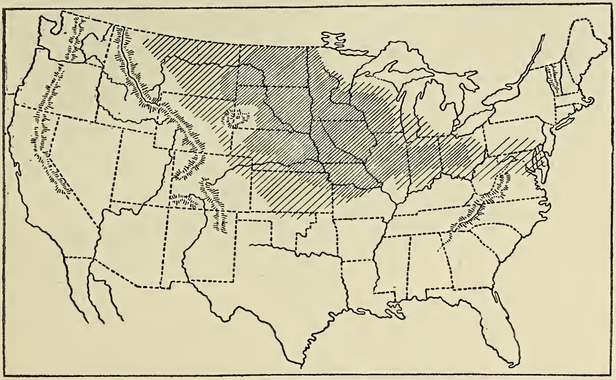


Mean Surface Temperature. 1906.

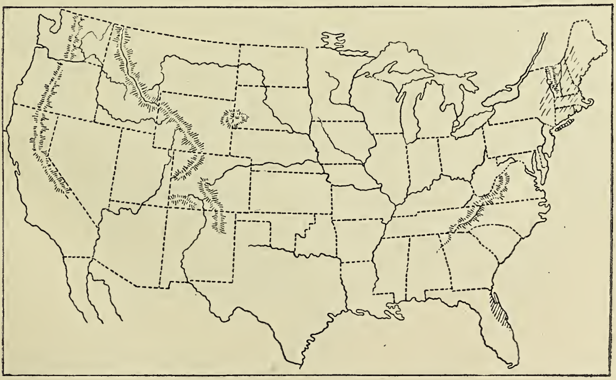


Departure from Normal Temperature 1906, March 1-October 3.

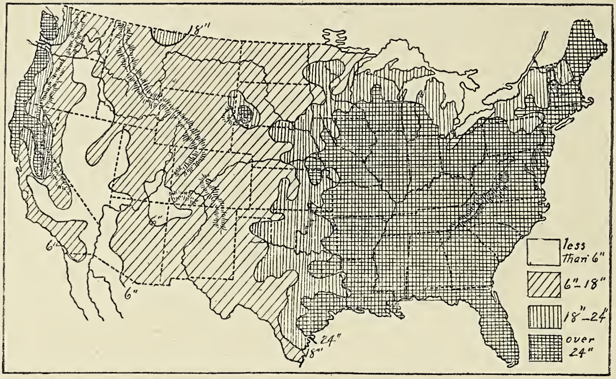
Maps showing distribution of potato rot, in a favorable and an unfavorable year. See accompanying United States weather maps for the years 1903 and 1906. Departures from Normal Precipitation for the Crop Season of 1907, March 1.



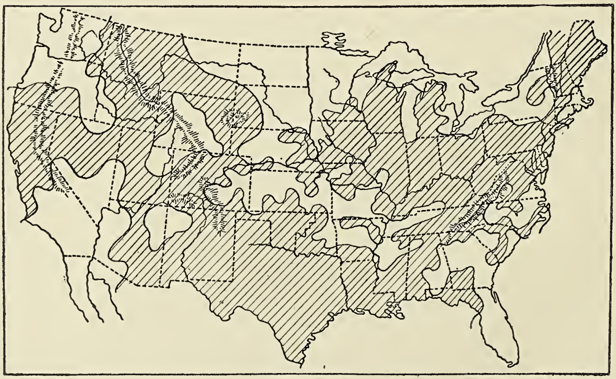
Potato Rot in 1903.



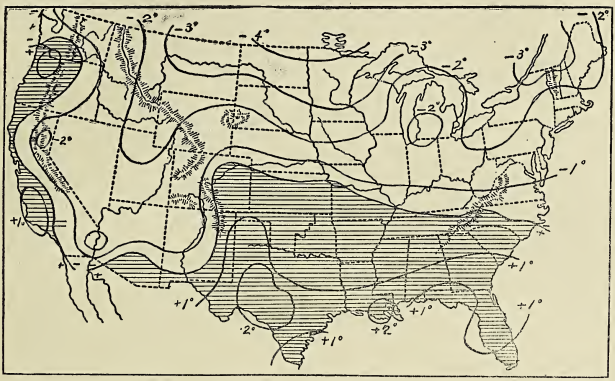
Potato Rot in 1906. Long Island and Florida.



Total Precipitation for the Crop Season of 1907. March 1-September 30.



Departures from Normal Temperature for Crop Season of 1907, March 1-September 30. Shaded portions show excess, unshaded portions deficiency.



Departures from Normal Temperature for the Crop Season of 1907 from March 1 to September 30.

THE FLORA OF IOWA ROCK.

A SMALL ROCKY ISLAND IN PUGET SOUND.

During the summer of 1908, in connection with work at the Marine Biological Liboratory, located at Friday Harbor, Washington, two visits were made to an interesting little island lying several miles to the south of the Station. The position of this island gave special interest to its algal flora; and, its borders, with adjacent shore lines, constituted one of the richest collecting grounds of the region. The name "Iowa Rock" was proposed for this island, and local revenue officers have taken steps to make this name official on the government maps of that region.

Our little island,—one of the tiny ones of that wonderful archipelago of Puget Sound,—is a solid mass of rock rising from the waters of San Juan Channel. It stands near the most western extremety of Lopez island, and at a point opposite the southern end of San Juan island. The longer dimension of the rock extends in a northwest and southeasterly direction, parallel to, and directly bordering upon the Strait of Juan de Fuca. The outward face of the rock is, as a result, exposed to the full force of the winds and waves of the broad Sound which near at hand merges with the waters of the Pacific ocean.

Iowa Rock is about 100 yards long with an average breadth of perhaps fifty yards. The apex of the rock is fully fifty feet above the water line. Separating it from the main-land of Lopez is a channel nearly one hundred yards wide through which the tidal currents sweep with great force. The rock is a highly metamorphosed limestone, dipping toward the Strait. The declination in this direction accounts in a general way for the topography of the island and also explains, no doubt, its escape from complete destruction by the waves.

The seaward face of the island is steep and rugged, broken into multitudes of points and depressions through the numerous fractures. The shoreward side of the rock slopes more gently, and is quite irregular in outline. Near the top of the rock a considerable quantity of soil has accumulated, to the leeward of the crest. Elsewhere the rock was quite bare.

The conspicuous plants found growing upon the island and along its shores were listed, and are given below. On the landward side of the rock, sheltered from the full force of the Strait winds by the rocky back bone of the island a number of seed plants have gained a foothold. Most of these, however, lead a precarious life. The few normally aborescent forms are dwarfed to mere bushes. The oak, *Querus garryana*, Dougl., which, in more favored habitats becomes a stately tree, is here sprawling and but a few feet in height. Most of the herbaceous forms, as might be anticipated are strongly xerophytic. The outward faces of the rock were barren of seed plants, due in part to scarcity of soil, but primarily to the severety of the winds. The land flora is therefore restricted almost exclusively to the sheltered hollows of the island on the side away from the open sea.

With respect to the water plants the distribution of the dominant forms is reversed, the seaward face having by far the richer flora. On this side toward the Strait, the water deepens rapidly, being fully thirty feet in depth at a distance of seventy-five feet from the water's edge, as witnessed by the narrowness of the kelp zone. The daily tidal fluctuation here is about ten feet, and the shores on this side are strongly lashed by the waves of the open Sound. The algæ growing here were not only unusually vigorous, but quite free, as well, from diatoms and other attached forms.

Most conspicuous of the marine algæ here, as elsewhere on these coasts, is *Nereocystis luetkeana*, P. and R. These plants grow with vigor unusual for the region upon the submerged shores of Iowa Rock. Local fishermen report plants over eighty feet in length from this point, and no doubt larger ones are developed there. as the strong waves and tidal currents would favor their elongation. The adjacent shares of Loopez island. distant only a few rods, bore splendid specimens of *Egregia menziesii*, Aersch., but none of these was found on Iowa Rock, the shores being probably too precipitous for them.

While the subtidal brown algæ, including Nereocystis, Alaria, Desmarestia, etc., were numerous and well developed, there was a poverty of inter-tidal representatives of this group. Only a few dwarfed specimens of Fucus and Colpomenia were found. These seem unable to maintain themselves on the rocks in the face of such wave action as is here encountered. On the other hand, the inter-tidal red algæ were conspicuous. The dashing of the spray doubtless facilitated the growth of such forms as Corallina, Amphiroa, Melobesia, Prionitis, etc. The sub-tidal reds were also well represented by Nitophyllum, Odonthalia, Ceratothamnion, Sarcophyllis, etc.

It should be borne in mind that the list of algæ from Iowa Rock given below includes only the relatively large and more conspicuous plants, and those growing there at one time (July 14, 1908). A detailed study, especially of the smaller forms, would add many names to the list, and observations continued through the succeeding seasons of the year, would likewise greatly extend it.

My thanks are due Dr. T. C. Frye, Professor of Botany, State University of Washington, for assistance in determinations.

Plants Noted Growing on Iowa Rock July 14, 1908.

Algae.

Chlorophyceæ—
- Ulva lactuca Wulf
- Cladophora sp.
- Codium mucronatum f. californicum J. Agardh.

Phæophyceæ—
- Laminaria bullata Kjell.
- Hedophyllum sessile Setch.
- Costaria turneri Grev.
- Alaria valida Kjell. & Setch.
- Nereocystis luetkeana P. & R.
- Desmarestia aculeata Lam.
- Desmarestia ligulata f. herbacea J. Agardh.
- Colpomenia sinuosa D. & S.
- Fucus evanescens Agardh.

Rhodophyceæ—
- Porphyra perforata J. Agardh.
- Iridaea laminarioides Bory.
- Nitophyllum ruprechtianum J. Agardh.
- Odonthalia dentata Lyngb.
- Polysiphonia sp.
- Microcladia borealis Ruprecht.
- Prionitis lyallii Harvey
- Sarcophyllis californica J. Agardh.
- Corallina officinalis L.
- Amphiroa tuberculosa Endl.
- Melobesia marginata S. & F.
- Ceratothamnion pikeanum var laxum S. & G.
- Gloiopeltis furcata J. Agardh.

Iowa Rock, seen from the south, and showing the side bordering on the open waters of Puget Souud.

Iowa Rock in the middle distance. The foreground shows the shore of Lopez island and in the distance is seen the southern end of San Juan island.

Mosses.

Eurynchium oreganum L. & J.
Grimmia sp.
Polytrichum juniperinum Wild.

Pteridophyte.

Polypodium occidentala (Hook.) Maxon.
Selaginella rupestris (L.) Spring.

Gymnosperms.

Pinus contorta Dougl.

Angiosperms.

Monocotyledons—
- Phyllospadix scouleri Hook.
- Aira caryophyllea L.
- Distichlis spicata (L.) Greene.
- Elymus arenarius L.
- Allium acuminatum Hook.
- Quamasia quamash Pursh Coville
- Fritillaria lanceolata Pursh.
- Zygadenus venenosus S. Wats.
- Piperia unalaschensis (Spreng.) Rydberg

Dicotyledons—
- Salix scouleriana Barratt
- Quercus garryana Dougl.
- Rumex conglomeratus Murr.
- Polyganum nuttallii Small
- Salicornia ambigua Michx.
- Cerastium arvense L.
- Berberis aquifolium Pursh.
- Sedum spatulifolium Hook.
- Sedum stenopetalum Dougl.
- Ribes divaricatum Dougl.
- Schizonotus discolor (Pursh.) Raf.
- Rubus macropetalus Dougl.
- Rosa nutkana Presl.
- Fragaria chiloensis (L.) Duch.
- Amelanchier florida Lindl.
- Pyrus diversifolia Bong.
- Trifolium variegatum Nutt.
- Vicia americana Muhl.
- Lathyrus maritimus (L.) Biegl.
- Epilobium angustifolium L.
- Daucus pusillus Michx.
- Lomatium nudicaule (Pursh.) Coult & Rose
- Statice armeria L.
- Micromeria chamissonis (Benth.) Greene
- Plantago maritima L.
- Valerianella congesta Lindl.
- Hypochaeris radicata L.
- Sonchus oleraceus L.
- Grindelia oregana A. Gray
- Solidago tolmieana A. Gray
- Aster douglasii Lindl.
- Achillea millefolium lanulosa (Nutt.) Piper

THE ACTION OF MANURE ON A CERTAIN IOWA SOIL.

BY E. B. WATSON.

The soil on which these studies were made was Southern Iowa loess from the experiment field in Decatur county, Iowa[1]. It is a fine loess soil containing considerable clay with the silt, and enough organic matter in the surface to make it dark brown. This loess differs from that of both eastern and western Iowa in its color, which is grey rather than yellow. It is the prevailing type of soil in southern Iowa.[2] The field from which the sample was taken had been in cultivation thirty or forty years, and in that time had probably produced no clover crops. The productiveness was quite low owing to continuous cropping with grain and poor cultural methods.

On the experiment field located on this farm it was noted that manure increased the growth of all crops experimented with, but the results with clover were the most striking. In fact clover was almost a complete failure on the untreated plots, but it produced a very good stand and growth on the plots treated with manure. Laboratory work was undertaken to ascertain the reason that manure had this effect on the soil, and clover was chosen as the indicator because it responded so readily.

A sample of soil was secured from the field in October, 1905. A short series of gallon pots were first run to find out if stable manure would benefit the growth of clover in the greenhouse in the same way that it did in the field. An application at the rate of sixteen tons per acre was chosen because it is double the usual application in field experiments, and it was desired to get as decided differences as possible by any treatment. The area of the surface of the soil in the pot is .23 sq. ft. and 76.8 grams per pot equals an application of sixteen tons per acre. The manure used was fresh cattle excrement containing no bedding. This contained 11.8 per cent of dry matter and .23 per cent of nitrogen. Average barnyard manure contains .5 per cent nitrogen, which would equal .384 g. per pot. To bring the amount of nitrogen in the application up to this standard, 167 g. of the manure were used.

Plate I, fig. 1, shows two of the pots seventy-nine days after planting.

Pot 1 is the check and it shows the poor stunted growth of the clover on the untreated soil. Pot 3 was treated with manure. The clover on this pot has made a fine normal growth, showing that the soil has been changed from a poor medium for clover growing to a very good one. This experiment gave the desired information, showing that the soil responded to the action of manure in the greenhouse as well as it did in the field. Results corresponding to the above were obtained in each of the series run in the subsequent work.

The first and most evident conclusion in regard to the cause of the better growth of the clover is that the manure furnished plant food which the soil

[1]Bulletin 98. Iowa Exp. Sta.

[2]Bulletin 82. Iowa Exp. Sta.

lacked, but there are other possible explanations, and these studies were undertaken to analyze this action. For convenience the work is divided into the following heads:

The Acidity of the Soil.
The Physical Effect of the Manure.
The Bacteriological Relations.
The Plant Food in the Manure.
The Antitoxic Action of the Manure.
The Toxic Effect of Cockleburs.

As far as could be learned, very little work has ever been done along this line, so it was an uncharted field. There were no paths to follow, and often the investigations led to no profitable results. Clover was found to be a difficult plant to grow in the greenhouse so that the pots would each start off with an equal number of thrifty vigorous plants. Without this even start results are not comparable. The small seedlings are sensitive to any adverse influence, but after the plant becomes thoroughly established, it can shift for itself very well.

In the series reported in this work the pots were filled with soil which was mellow and free from lumps, at optimum water content, and packed in with the hand fairly tight. This packing prevented, in large measure, the troublesome settling and cracking of the soil in the pots. The optimum physical condition was obtained and the treatments thoroughly incorporated with the soil by the following method. Sufficient soil to fill a pot was weighed out, placed in a pan, the treatment, if any, was added and the whole mixed as thoroughly as possible. It was then wet down well and let stand until it had dried so that the soil could be handled readily. Then it was thoroughly mixed and rubbed between the hands. This process was repeated two or three times to insure thoroughness and the soil was then placed in the pots. The water was applied both at the surface and at the bottom of the pots. A small tube was placed in the soil leading to an inch of gravel in the bottom of the pot. This tube conducted water to the reservoir, allowing it to come up by capillarity, and preserving the physical condition of the soil. The surface watering prevented accumulation of salts on the surface, which the capillarity tended to bring up.

The clover was seeded with a small dibble, one-half inch deep, one seed in a place, and twenty to twenty-five seeds to the pot. The plants were later thinned down to the required number, usually ten or twelve. When the clover was four weeks old it began to feed on the soil. Before this time it grew on the nourishment in the seed.

THE ACIDITY OF THE SOIL.

Clover is a plant that seems especially susceptible to the influence of acidity in the soil, and in many places, for instance Rhode Island,[1] the addition of lime is all that is necessary to insure a good growth of clover. Furthermore, the soils of southern Illinois, which are in many regards similar to those of southern Iowa, have been found to be acid.[2] It seems very possible that this soil is acid and to test this question a pot was treated with lime in the first series. The lime was added at the rate of one ton per acre, being 4.8 g. to the pot in the form of finely powdered limestone.

[1]Sixth An. Rept. R. I. Ag. Ex. Sta., p. 227. (1893.)
[2]Illinois Ex. Sta. Bull. 99.

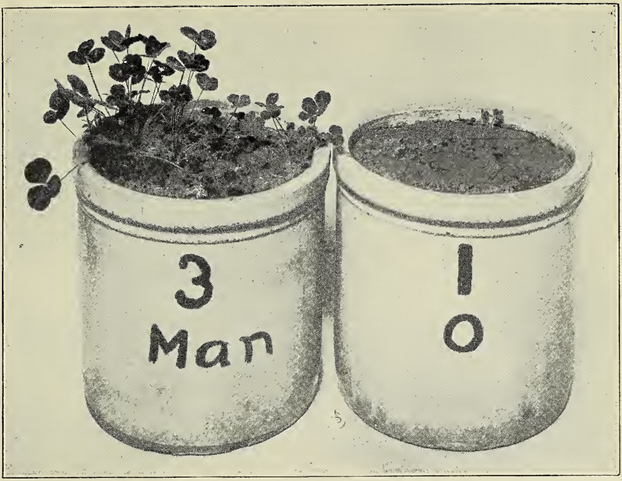


Plate I. Fig. 1. Effect of manure.

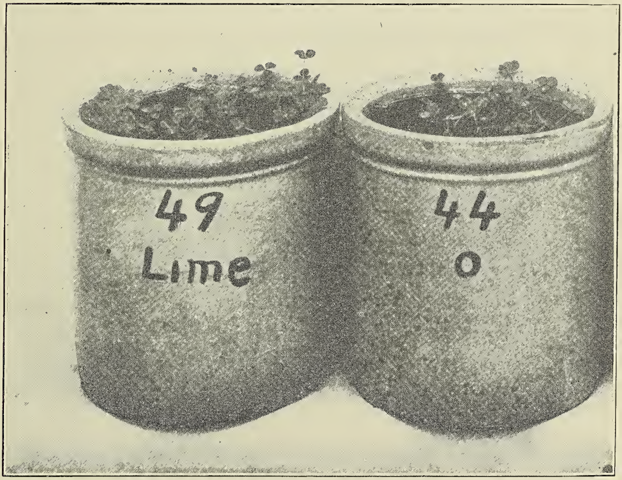


Plate I. Fig. 2. Effect of lime.

The pots were planted December 30, 1905, and photographed sixty-five days after planting. The pictures are shown in Plate I, fig. 2.

Pot 49 was treated with lime and pot 44 was untreated. The picture shows that the effect of the lime treatment was nothing. There is more foliage in pot 49 but there are twice as many plants in this pot. It seems safe to draw the conclusion that the lime has not benefited the clover and that the soil is not acid.

But this matter of acidity is so important that it seemed best to settle it beyond question. For this reason it was tested again both alone and in combination with other treatments. The series of pots for this purpose were filled with soil and planted February 24, 1906. Most of the treatments were run in duplicate, and lime was tested alone, with manure. with mineral fertilizers, with green manure, with mineral fertilizers plus peat, and with mineral fertilizers plus green manure. In both the pots that had the combination of green manure, mineral fertilizers and lime, No. 82 and No. 89, a stand was not secured and the plants that did survive did poorly, so these pots are not taken into account.

The pots were harvested June 1st. The followi ~ table gives the treatment of the pots and the data secured at this time. In lumn the relative standing of the different pots are shown when c h the checks, the average of which is placed at 100.

EFFECT OF LIME ON THE GROWTH OF CLOVER.

Pot	Treatment	Gr'n wt. g	No. Plants	Wt. per Plan	Rel'tive Weight
71	Check	17.15	13	1.31	104
72	Lime	17.45	14	1.24	99
73	Man.	43.30	13	3.33	265
75	Man. L.	35.50	13	2.73	218
76	N. P. K.	33.30	12	2.77	220
77	N. P. K. L.	30.80	13	2.36	188
78	Gr. Man.	21.80	12	1.81	144
79	Gr. Man. L.	22.80	13	1.75	139
80	Peat N. P. K.	35.45	13	2.75	220
81	Peat N. P. K. L.	32.65	12	2.72	216
83	Check	15.60	13	1.20	96
84	L.	20.05	13	1.54	122
85	Man. L.	25.05	10	2.50	199
86	N. P. K. L.	36.75	13	2.83	225
87	Gr. Man.	20.30	14	1.45	116
88	Gr. Man. L.	20.95	15	1.39	111
90	Peat N. P. K. L.	35.55	13	2.73	218

The following table shows the average of the duplicates of the limend and unlimed pots of each treatment arranged for convenient comparison, and the two groups averaged.

EFFECT OF LIME, AVERAGED.

Treatment	Limed		Unlimed	
Check	Average 72 and 84	110	Average 71 and 83	100
Manure	Average 75 and 85	209	73	265
N. P. K.	Average 77 and 86	206	76	220
Green manure	Average 79 and 88	125	Average 78 and 87	130
Peat, N. P. K.	Average 81 and 90	217	80	220
Average		173		187

The data given in these tables show that when used alone, lime gave a slight benefit, but when used with manure, mineral fertilizers or green manure, there was an apparent disadvantage from its use. When all the pots are averaged, the limed pots are fourteen points below the unlimed ones. We are not justified in concluding from this that lime injures the growth of clover. These few points are within the limits of error. However, we certainly are justified in deciding that lime does not help.

The soil was tested for acidity as follows: water was percolated through the soil in a pot, 100 c. c. of this was secured and filtered, boiled a few minutes to expel CO_2 and tested with N-50 KOH and HNO_3 using lacmoid as an indicator. The solution was found slightly alkaline.

We conclude that this soil is not acid and the action of the manure in increasing the growth of the clover was not to correct acidity.

THE PHYSICAL EFFECT OF THE MANURE.

To what extent does the physical effect of the manure on the soil influence the growth of the crop? Agricultural writers often make the statement that manure puts the soil in better condition, or adds tilth to the soil, but definite information as to just what the physical action of the manure on the soil may be, is very scarce. Manure lightens the soil and makes it easier to cultivate, but what are the exact changes in the physical properties of the soil? How does the manure affect its specific gravity, its volume weight, its relation to heat, and above all, its relation to water. Then after these questions are answered there is the question of still greater importance, how do these changed physical conditions affect plant growth? Everybody has taken it for granted that there are changes and that they benefit plant growth, but just why and how it happens, nobody has taken the trouble to ascertain.

The following references contain practically everything of value which is published in English on this point.

Aikman[1] after discussing the plant food brought by the manure, says, "We must seek for perhaps the most valuable properties of manure in its indirect influences," and these are enumerated as 1st, a source of humus; 2d, influence on texture of soil during fermentation; 3d, heat of soil by decomposition; 4th, carbonic acid given off in fermentation.

Hilgard[2] says this: "Unhumified organic matter lightens the soil, rendering it more previous to air and water, and in its progressive decay it gives off carbonic gas which is active in soil decomposition."

King[3] says: "One of the most important effects of stable manure when applied to soils is its tendency to establish parting planes in the soil which favor both the formation and maintenance of strong granulation." He also says: "When a soil is treated with farmyard manure which has become well incorporated with it, it has the effect of causing a stronger rise of the deeper soil moisture into the surface three feet, where it is most needed in the production of crops."[4] A table is given showing 1 per cent more moisture in the surface foot of the manured plot. But this may be due not to increased capil-

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[1]"Manures and Manuring" Aikman, p. 273.
[2]"Soils" Hilgard, p. 135.
[3]Year Book U. S. Dept. Agri. 1895, p. 168.
[4]"Physics of Agriculture." King. p. 172.

larity as he states, but to retarded evaporation. It will be noted that he claims this effect for the manure, after it is well incorporated with the soil.

Storer[5] says this: "Naturally enough, the power of the soil to hold water tends to retard evaporation from the soil." He gives a table of Schuebler showing that as the content of clay or vegetable mold increased, the amount of water evaporated from the soil decreased, and he adds, "It will be noticed that, in proportion as a soil absorbs more water by imbibition, so much the less water does it give off through evaporation."

Voelcher[6] cites the case of two soils, powdered and kept in a heated room until air-dried. One from a wheat field contained 6 per cent organic matter and retained 4.7 per cent of moisture. The other soil from a permanent pasture had 22 per cent of organic matter and held 22.35 per cent of moisture.

These few references represent the sum of available knowledge of the physical effects of organic matter in the soil, but they do not give the specific information wanted. It should be kept in mind that though manure is organic matter, it is not, when first added to the soil, either vegetable mold or humus.

A test was made of the effect of manure and peat on the water holding capacity of soils and the rapidity with which the water drained away. Soil tubes two inches in diameter and twelve inches high, with perforations in the bottom, were used; peat and manure were each added to the poor loess soil at the rate of 1.5 per cent. The per cents of water held at the different periods were as follows:

EFFECT OF MANURE AND PEAT ON WATER HOLDING CAPACITY.

Soil	Saturated	Saturated and settled	Drained				
			1 hr.	20 hrs.	44 hrs.	3 da.	5 da.
Loess	57.5	54.2	50.6	50.	49.2	48.9	48.
Loess and manure	57.2	55.2	53.7	51.9	50.8	50.4	49.5
Loess and peat	57.6	54.3	51.8	51.4	50.8	50.5	49.6

The same net weight of soil was put in each tube, but the soil containing the manure was a little more bulky; the fact that the latter was jolted down to the same level as the others, made it more compact and slightly reduced its water holding capacity at first. The tubes were allowed to set in the water three days and this settled them somewhat and lessened their water holding capacity as the figures show, but while they were in the water the manured tube settled less than the others, and its capacity was left 1 per cent greater. When they were allowed to drain, being kept covered to prevent evaporation, the manured tube lost its water more slowly than the check. The peat tube behaved nearly like the manured tube. These facts show that peat with respect to the retention of moisture affects the soil almost like the manure, and that they both helped to retain the water in the soil when it was near saturation.

The two following experiments were worked in co-operation with E. E. Humbert, a senior student at the time. The soil used was old worn Marshall loam

[5]"Agriculture." Storer. Vol. 1, p. 110.

[6]Journal Royal Agl. Society, Vol. 18, p. 347.

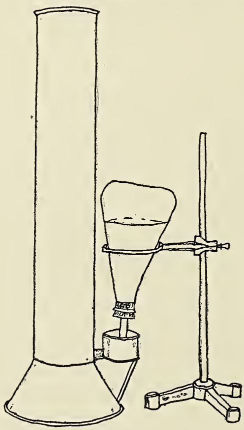
taken from the Wisconsin drift. In the first experiment a test was made of the effect of manure and peat on capillarity. The soil was placed in 5 ft. glass tubes, 1 inch in diameter, which were held upright in a frame. The lower end of the tubes were placed in shallow pans of water. The following table shows the height in inches to which the water rose at the different periods. The manure and the peat were added on the dry basis.

EFFECT OF MANURE AND PEAT ON CAPILLARITY.

Soil	14 hrs.	38 hrs.	4 da,	5 da.	8 da.	11 da.
Poor soil	11.2	14.5	17.7	18.7	20.5	22.1
Poor soil plus 1% manure	12.	15.2	18.2	19.	20.7	22.3
Poor soil plus 2% manure	11.	13.5	16.	16.7	18.	20.
Poor soil plus 1% peat	14.2	18.5	22.	23.	24.5	26.1
Poor soil plus 2% peat	15.2	19.	21.7	22.7	24.2	26.2

This data shows that manure had practically no effect on the capillarity of the soil. The heavier application retarded it slightly. Peat, however, increased the capillarity quite markedly, but there was practically no difference whether the amount of peat added was 1 per cent or 2 per cent. This experiment is defective on account of the lack of duplicates. Each tube should have had at least two duplicates, and four would have been better.

The rate of evaporation of water from the surface of the soil both manured and unmanured, was tested by the following method which was the result of the experience gained in a number of similar experiments. Soil tubes 4 inches in diameter and 30 inches tall, constructed as shown in the accompanying illustration, were used. These had a feed tube 2 inches in diameter near the bottom. Emptying into this feed tube was the inverted E. flask filled with distilled water. This provided an automatic self-feed and kept the water in



Evaporation Tube

the base of the soil tube at all times just 24 inches below the surface of the soil. It was found by previous experiments that the amount of water supplied to the soil was not a true measure of the amount evaporated. The amount of water in the soil varied greatly and without apparent cause. Tubes kept with the supply of water constantly 24 inches below the surface would vary in weight from week to week. The true measure of the evaporation was obtained by combining the loss or gain in weight of the tube of soil with the amount of water supplied.

Five tubes of each soil were run. The necessity for so many duplicates is seen by examining the accompanying table. The duplicates do not keep close together, but the averages tell a very consistent story and it is felt that they can be relied upon. The tubes were prepared by placing 2 inches of gravel in the bottom, then filling to within 6 inches of the top with the same kind of soil in each. They were then run blank for several weeks and their behavior noted. The variation between the different tubes was very slight. The surface soil was then placed in the top of the tubes, the untreated soil in five tubes and the soil treated with 1.67 per cent of dry manure in the other five tubes. This gave the same subsoil to all the tubes, the difference lying in the surface 6 inches. Mr. Humbert ran the series for about two months including the preliminary tests, and secured the results given in the third and fourth columns. On his departure I took charge of the experiment and secured the data for the last month. The results are given in c. c.

EVAPORATION TEST. BEGUN JUNE 24, 1907.

Tube No.	Soil	Evap. in 19 days	Aversge	Evap. in next 31 days	Average
6	Poor soil	184		259	
8	Poor soil	193		262	
10	Poor soil	176	183.8	255	255.4
12	Poor soil	180		261	
15	Poor. soil	186		240	
4	Poor soil plus manure	171		235	
9	Poor soil plus manure	165		260	
11	Poor soil plus manure	190	173.6	258	246.4
13	Poor soil plus manure	164		238	
14	Poor soil plus manure	178		241	

This table shows that manure retarded evaporation to the extent of 10.2 c. c. during the first nineteen days, and 9 c. c. during the next month. Manure retards evaporation of water from the soil, but the effect is very slight. The amount of manure applied was equal to fifty-eight tons of average barnyard manure to each acre of soil. When the amount of water saved is calculated to inches it equals 1 inch in 505 days, if evaporation should go on at the summer rate all the time. Calculated in per cents it shows that this enormous application of manure, which is several times as much as the usual application of manure in field practice, prevented only 4.4 per cent of the evaporation of water from the soil. This is surprisingly small and evidently not capable of producing very profound effects on the growing crop.

To sum up the findings in regard to the physical effects of the manure on the soil, it has been shown that fresh stable manure decreases the volume weight of the soil, makes it more porous and increases its water holding capacity. It retards percolation and increases the water retaining power of the soil. It has practically no effect on capillarity and it hinders evaporation to a limited extent. Peat, when tested and observed, acts in a very similar manner except in regard to capillarity.

Stable manure causes the soil to hold and retain more water, but does the soil give up this extra water to the growing crops? How does manure effect the drouth line?

In reference to this point Snyder[1] says: "A soil rich in humus not only absorbs more water, but holds it more tenaciously in time of drouth than a soil poor in humus. As is well known, soils which are properly manured and thus supplied with abundant humus, retain more water and yield it up more slowly and evenly to growing crops than unmanured soils." From some experiments by Sachs[2], it appears that plants cannot exhaust the retentive soils so completely of their water as they can the soils which are non-retentive. His experiment is summarized in this table.

EFFECT OF HUMUS ON CAPILLARITY.

Soil	Capacity for capillary water %	Wilting point for tobacco plant. % water
Loam	52	8
Mixture of humus and sand	46	12
Coarse sand	21	1.5

Experiments by Hellriegel have shown that any soil can supply plants with all the water they need, and as fast as they need it, so long as the moisture within the soil is not reduced below one-third of the whole amount that it can hold.

These experiments suggest that soil treated with stable manure might retain its extra moisture in time of drouth to such an extent that plants would not be able to get it. However, the general impression is that this water is available. In fact, Professor Spillman in Farmers' Bulletin 245 says that this extra water is readily available to crops, but gives no data or authority to support the statement.

Three experiments were run to secure data on this point. The last one which was the most elaborate of the three, is here reported. The first two gave results similar to the last one.

The effects of manure on the drouth limit was tried by ascertaining the per cent of moisture in some clover pots from a series which was finished. This per cent of moisture was found by noting the weight of the different pots at the different stages, as optimum water content, first wilt, etc., and then at the close of the experiment making a moisture determination of the total soil in the pots, finding the net weight of the soil, and then from this data calculating the per cent of the moisture held at the different stages. The pots used had been planted to clover February 24th and this experiment began June 7th, therefore the clover was of good size. The data secured was as follows:

[1]Year book, U. S. Dept. Agri., 1895, p. 138.

[2]Storer's Agriculture, Vol. 1, p. 111.

EFFECT OF MANURE ON DROUTH LIMIT.

Pot	Treatment	Net weight soil g	Per cent of moisture in the soil				
			Optimum	First drouth	Leaves dying	½ l'ves brown	Dead
71		4020.5	20.9	9.3	8.7	7.9	7.5
83		3985.	20.7	8.7	8.2	7.4	7.0
73	Manure	4093.7	19.9	10.	9.5	8.3	8.0
	Difference			1.	1.05	.65	.75

It is seen that the manured pot had 1 per cent more moisture when drouth first overtook it, and .75 per cent more when the crop died. These figures are not taken to mean more than that the drouth limit is higher in soil that is manured than in untreated soil, but as each experiment gave the same result, it is safe to claim that much. As the result of the work on the water holding capacity of soils, it was decided that manure enabled the soil to retain more water. It seems from the above data that a plant will wilt in a manured soil when there is more water in it than in an unmanured soil. In other words the extra water held by the manured soil is not all available to growing crops, and probably none of it. Manure can not help the growth of clover on account of its adding to the soil an increased ability to retain water, for it does not give this water up to crops.

The above study of the physical action of manure on the soil is not considered by any means to be exhaustive, but it was not thought necessary to carry it to completion because the soil in these experiments was kept in the best possible physical condition, and it was hard to see how any material as manure could benefit it to such an extent as to materially aid the crop, especially as the effects of the manure on the soil were found to be so very slight. Besides, a simpler method of attack was found.

The second way by which the problem of the physical effect of the manure was attacked was to study the action of a substance that gave the same physical effect without at the same time carrying plant food or other possible beneficial properties as does the manure. The above studies show that peat does fairly well in regard to duplicating the effects of the manure, and although peat carries some plant food, it is not in an available form.

A series was run to test the effect of peat. Mineral fertilizers were added to the peat to make an artificial manure, giving both the physical effect and the plant food. The peat used lost 50 per cent on ignition. The series was planted February 24th. Pictures were taken May 3d. Plate II, fig. 1, shows representative pots, both untreated and treated with peat.

EFFECT OF PEAT.

Pot 76 had mineral fertilizers added to it, and pot 80 had mineral fertilizers and peat added to it. There is no apparent benefit derived from the use of peat.

Green weights were obtained June 1st. The series, with the treatment and the results are given in the following table.

PEAT SERIES.

Pot	Treatment	Weight g	No. of plants	Wt. per plant g	Relative wts. Av. ch'ks, 100
76	N. P. K.	33.3	12	2.77	100
77	N. P. K. L.	30.8	13	2.36	
73	Manure	43.3	13	3.33	146
80	Peat and N. P. K.	35.45	13	2.75	107
81	Peat and N. P. K. L.	32.65	12	2.72	105
90	2 peat and N. P. K. L.	35.55	13	2.73	106

It is seen that the three peat pots run remarkeably close together, and that even when double the portion of peat was added there was no advantage from its use. Although the peat here shows a slight gain over the pots having no peat, it is within the limits of error and not to be compared with the growth due to manure, which was 146. We can safely say that this experiment shows no benefit from the use of peat.

The investigations have shown this: peat has a decided physical effect on the soil and while it is not identical with that of manure, still it is not far different. But peat does not benefit the growth of clover. Manure does. Therefore it is not the physical effect of the manure which is responsible for the better growth of the clover, when the clover is grown in the greenhouse and the soil is put in good physical condition and well supplied with water.

The question of the physical effect of the manure was attacked in a third way, namely, by using a liquid manure that carried fertility without at the same time giving the physical effect that the regular manure did. It is reasonable to assume that the physical effect of the manure lies in the coarse insoluble part and that the soluble portion would have little, if any, such effect. However, it was found that manure leachings applied to the surface of the soil retarded the loss of water in a very decided manner. King[1] found the same thing: He found that wetting the surface of a sand with the liquid which leached from farmyard manure decreased the rate at which water was lifted 16 inches and evaporated from the surface 49.64 per cent. The explanation of this is that the soluble organic matter clogged the pores in the soil, stopping to some extent the capillary rise and evaporation of the water, in much the same way that salts deposited at or near the surface hinder the movement of water in the soil. This is not to be considered as indicating that the leachings have anywhere near the same physical effect as the bulky manure. They have some such effect, but it is small in degree.

The main thing to be determined is, what effect does liquid manure have on the growth of clover as compared to the regular manure?

A series was planted March 7, 1906, to test this question and also the effect of smaller amounts of manure. "Manure extract" was used on pot 107. To obtain this the regular amount of manure was thoroughly mixed with water, and as it would not filter, the coarse material was strained and settled out by aid of the centrifuge. Considerable suspended matter remained, but probably not enough to have much humus effect. What was obtained was the soluble and very fine part of the sample of manure. A perfect elimination of coarse material was obtained in "manure leachings" which was the liquid which

[1]Wisconsin Annual Report, 1893, p. 197.

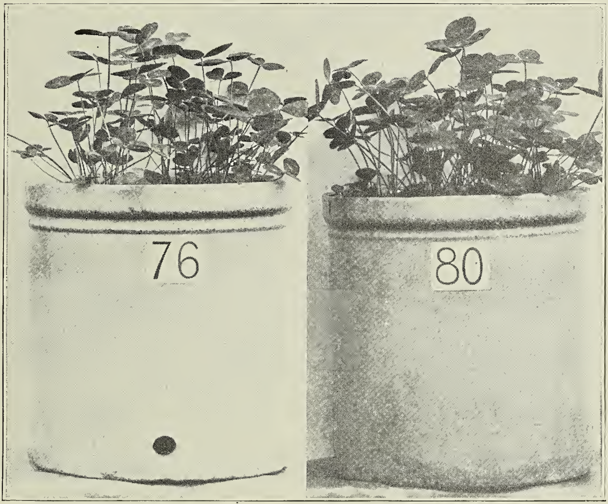


Plate II. Effect of peat.

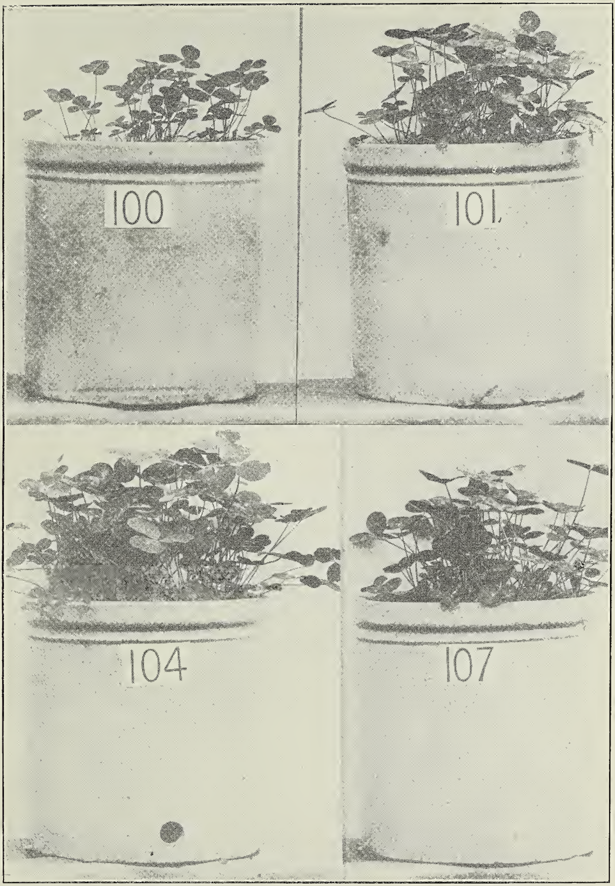


Plate III.

100—Check
101—Manure

104—Leachings
107—Extract

drained from a can of manure. This was allowed to stand until all fermentation ceased. It was then filtered and analyzed for nitrogen. 2,400 c. c. contained as much nitrogen as the regular amount of the manure. The potassium and phosphorus were assumed to be in about the same proportion. The same amount of nitrogen and approximately the same amount of potassium and phosphorus were applied in the leachings as in the manure. One-half and one-fourth of the above amount of leachings were applied to other pots to test the effect of smaller amounts.

Pictures were taken May 3d, and the main pots of the series are shown in Plate III,.

This picture shows the decided benefit of the manure, that the "leachings" gave more benefit than the manure itself and that the "extract" appears to be as good as the manure.

The series was harvested June 8th, and the following table gives the treatments of the different pots of the series and the results obtained.

LIQUID MANURE SERIES.

No. pot	Treatment	Green wt. g	No. of plants	Average per plant	Relative weight
100	Check	14.63	12	1.22	100
101	Manure	32.3	13	2.48	203
102	1-2 amt. manure	24.7	13	1.89	155
103	1-4 amt. manure	22.3	13	1.71	140
104	2400 c. c., leachings	47.7	12	3.97	323
105	1200 c. c. leachings	37.15	13	2.86	234
106	600 c. c. leachings	22.55	13	1.73	142
107	Manure extract	32.25	12	2.68	220

A study of this table shows that the "leachings" containing the same amount of plant food as the manure, gave twice the growth of clover. In fact, half the amount of "leachings" produced a little better gain than the full amount of the manure. It also shows that the "manure extract," or the soluble part of the manure, produced the same effect as the whole manure. This can only mean that the benefit lies in the soluble part of the manure, and as the soluble part of the manure certainly has much smaller physical effect than the insoluble part, it makes it very unlikely that the physical effect of the manure has any thing to do with the better growth of the clover.

We have arrived at the same conclusion; namely, that the physical effect of the manure is not responsible for the better growth of the clover, by three different lines of argument. To be sure no one of them amounts to absolute demonstration, still the accumulation of evidence is sufficient to justify the conclusion that in the greenhouse, other properties of the manure are responsible for the better growth of the clover on the manured soil.

THE BACTERIOLOGICAL RELATIONS.

The question of the influence of the bacteria brought by the manure, and the influence of the manure on the bacterial growth in the soil was studied, and has already been reported.[1]

[1]See Proc. Iowa Acad. of Science, XIV, 1907, p. 177.

The conclusion reached as a result of this work was that bacteria are in no way responsible for the beneficial action of the manure on the growth of the clover, for in the first place it was shown that the sterile manure was as beneficial as the unsterilized, and in the second place it was shown that when the whole pot was sterilized, the crop did not suffer.

THE PLANT FOOD IN THE MANURE.

How do plants feed and where does their food come from? The old humus theory as advocated by Thaer[2] was to the effect that "the fertility of the soil is really determined by its humus, for excepting the water, it is the humus alone that supplies nourishment to the plant in the soil." Liebig proposed a "mineral" theory which was directly opposed to this, and such was his great reputation and prestige that he carried the scientific world with him. Dr. A. Voelcker[3] said this: "The humus theory has retarded rather than promoted agricultural improvements. Happily it may be regarded at present as fully exploded." The transition from this extreme doctrine to the theories held today has been gradual. Undoubtedly plants can grow and thrive without humus or organic matter of any kind if mineral plant food is supplied in the proper proportion. Still, partially decayed organic matter is a help to the growth of plants. Liebig and his associates explained this by ascribing it to the physical effects of the organic matter. Later researches have developed the doctrine that this organic matter through processes of decay becomes broken down into simpler forms, and then can be used by plants, but that organic matter as such is not plant food. The nitrogen must appear as nitrates and the potash and phosphorus as soluble salts. The plant obtains its carbon from the carbon dioxide of the air, and never from the carbohydrates in the manure or the soil. For this reason it is customary to value manure in all writings of the present day according to the amount of the three elements, nitrogen, potassium and phosphorus found in it. It is also recognized that the organic acids produced by the manure or humus help to make plant food available which is not otherwise obtainable by plants. Growing crops exhaust the soil of a portion of the plant food contained in it, and this must be replaced or the soil will in time become exhausted. The enormous trade in commercial fertilizers is an outgrowth of this doctrine. Although this is the generally accepted view, there has lately been a question raised as to some of these points, especially the action of manurial salts in the soil.

The most natural assumption in studying the action of manure on this soil, is that manure helped the growth of the clover because it supplied plant food. If this is the case, then these elements supplied in forms as available as that in the manure, should give as good returns. This is the whole doctrine of commercial fertilizers in a nutshell. This point was thoroughly tested. The nitrogen was supplied as sodium nitrate, as a nitrate is the form in which nitrogen is used by the higher plants, and is more available than the nitrogen of the manure which is largely protein. The phosphorus in the first experiment was a solution of calcium phosphate. In later experiments sodium phosphate was used. Potash was supplied as potassium sulfate.

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[2]See Heiden Lehrbuch der Dungerlehr. Vol. 1.
[3]Journal Royal Agl. Society, 18, p. 345.

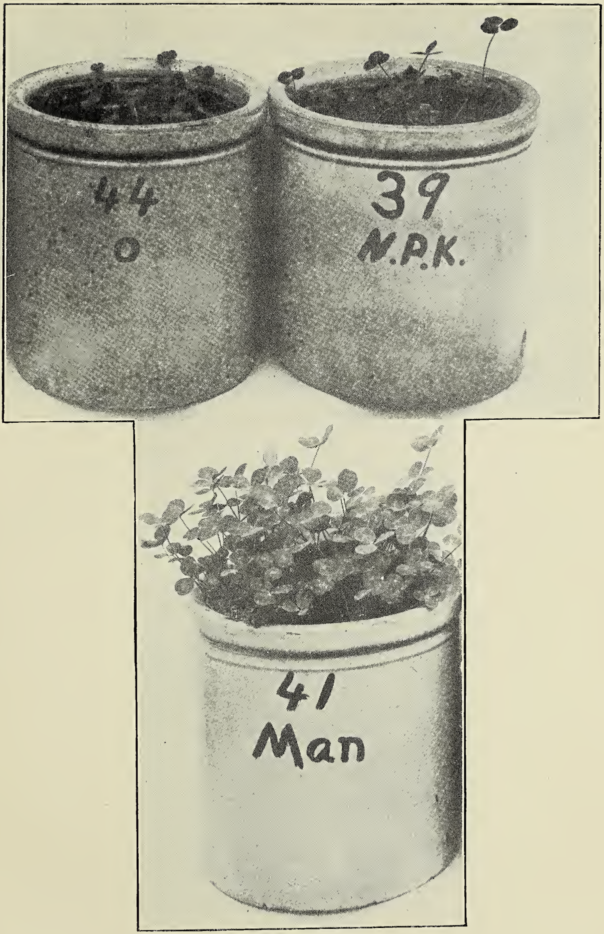

Plate IV. Manure vs. Mineral Fertilizer.

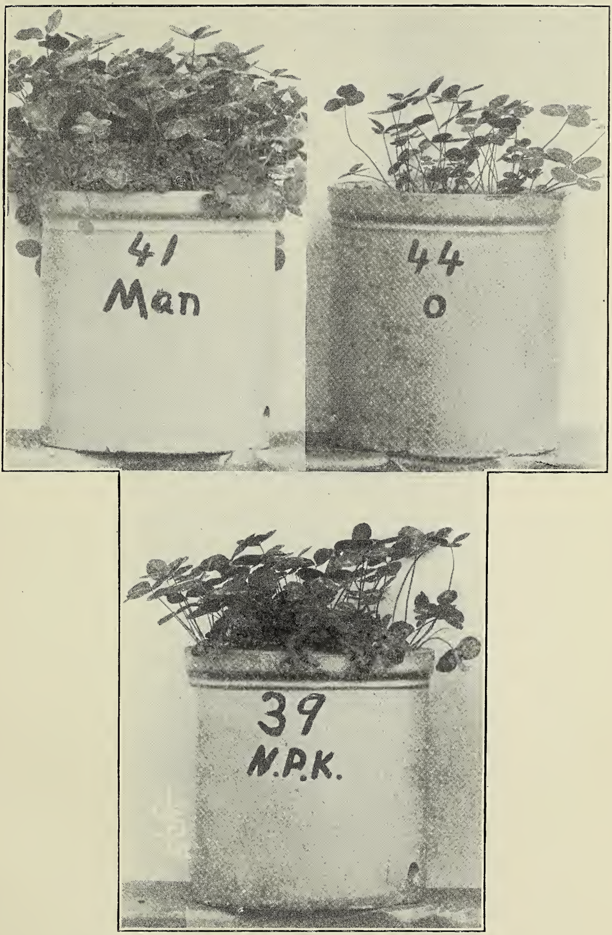

Plate V. The same pots as in Plate IV at a later date.

The first series to test the question was planted December 30, 1905. Pot 44 was the check, pot 41 was treated with cattle manure at the rate of sixteen tons per acre, and pot 39 was supplied with mineral fertilizers in amount equal to the plant food found in the manure furnished to pot 41. On March 5, or sixty-five days after planting a picture was obtained of these pots and shown in Plate IV.

MANURE VS. MINERAL FERTILIZERS.

The same pots were photographed again May 3d, when the clover was 124 days old, with the results as shown in Plate V.

THE SAME POTS AT A LATER DATE.

A study of these pictures is very interesting. The first picture shows that the manure helped the growth of the clover immensely, while there is very little benefit up to this time from the mineral fertilizers. The mineral fertilizers had the advantage, too, of being soluble while the manure was largely insoluble.

The second picture shows that the minerals have been helping the clover, and this pot is bidding fair to catch up with the manured pot. The check pot also has been growing much better than it did it first. It would seem that there was something in the manure that caused the soil to be a good medium for the growth of clover when it was quite young, but as the clover got older it was able to shift for itself and the mineral plant food helped it some. The stand varied so much in this series that it is difficult to make exact comparisons by means of the green weights, therefore they are not given.

Complete description of a later series is given, fully establishing the fact that the manure helped the growth of the clover far beyond the help given by the soluble plant food, and proving that the mineral plant food theory is not a satisfactory explanation of the action of manure on this soil.

A fresh sample of soil was secured from the field in October, 1906. The sample was pulverized and mixed as soon as it reached the laboratory and placed in closed cans to keep it as near to field condition as possible. Manure leachings, similar to that used in the last experiment described under the discussion of the physical effect of the manure, were analyzed and found to contain 1.005 per cent solid matter, .65 per cent ash, .02296 per cent nitrogen, .012 per cent phosphoric acid and .05294 per cent potassium. 870 c. c. of the leachings, therefore, contained .2 g. of nitrogen. This amount of nitrogen was found by previous experiments to be sufficient for the clover. 870 c. c. of leachings contained .0456 g. of phosphorus and .46058 g. of potassium. The pots 208 and 209 marked N. P. K. were given exactly the same amount of these three elements of fertility. The nitrogen was furnished in 1.212 g. of sodium nitrate, the phosphorus was found in .5271 g. of disodium hydrogen phosphate and the potassium in 1.0255 g. of potassium sulfate. To ascertain which one of these elements was responsible for the better growth of the clover, they were also applied separately as is shown by the table. For purposes of comparison two other carriers of nitrogen were tried, namely dried blood and peptone. .2 g. of nitrogen was supplied to each pot. 870 c. c. of the manure leachings were divided by distillation into two approximately equal portions, a distillate and a residue, and these portions applied to two different pots to find which one contained the plant food.

The series was planted October 19th, and harvested January 18, 1907, when ninety-one days old. The following table gives the treatment of each pot in the series, the green weight of the crop when harvested, and the relative weight of the crop on each pot.

OCTOBER PLANT FOOD SERIES.

No. pot	Treatment	Green wt.	No. plants	Relative weight	Average
200	Check	4.1	10	96	
201	Check	4.4	10	103	100
202	Manure leachings	7.9	10	186	
203	Manure leachings	9.5	10	223	205
204	Distillate from leachings	4.	10	94	
205	Distillate from leachings	4.6	10	108	101
206	Residue from distillate	10.1	10	237	
207	Residue from distillate	8.5	10	200	218
208	N. P. K	7.65	10	180	
209	N. P. K	6.85	10	161	170
210	Sodium nitrate	4.15	10	97	
211	Sodium nitrate	5.75	10	135	116
212	Dried blood	5.5	10	129	
213	Dried blood	5.95	10	140	135
214	Peptone	5.	10	118	
215	Peptone	5.45	10	128	123
218	Potassium sulfate	3.65	10	86	
219	Potassium sulfate	5.7	10	134	110
220	Sodium phosphate	6.75	10	160	
221	Sodium phosphate	5.65	10	133	147

The above table shows that the manure leachings have a relative standing of 205, while the distillate from this made no gain whatever. The residue resulting from the distillation gave as good gains as the fresh leachings. The point is thus proved from two directions that the fertilizing value of the manure leachings were not volatile but remained in the flask during distillation.

The next point is the effect of the mineral fertilizers. This is 170 which is considerably below that found for the manure.

What part did the different elements play? Taking the data as it stands, the evidence is that the nitrogen gave an increase of 16 per cent, potassium 10 per cent, and phosphorus 46 per cent, a total of 72 per cent which is very close to the gain resulting from the three together, 70 per cent. However, as the duplication was not very good in any of these cases, it is not wise to adhere too closely to these figures, but this probably is true; the phosphorus helps the most, the nitrogen next and the potassium the least of three elements. Concerning the different forms of nitrogen, the dried blood and the peptone seem to be as good as the nitrate, but as one of the nitrate pots had a standing of 135, it is not certain that these forms are better than the nitrate.

Several other series were run, for it was necessary to thoroughly establish the point that the manure had a beneficial action other than that attributable to the soluble mineral plant food found in it. Summing up these experiments where different samples of soil from this field, and both solid and liquid manure were used, the results show that if the clover on the manured pots is ranked as 100, the mineral fertilizers gave a growth equal to 75 in the first series, 93 in the second, 80 in the third, 80 in the fourth, 72 in the fifth and 61 in the last series. At no time have the minerals given as good growth as the manure. and in the earlier trials the amount of soluble plant food was much in favor of the mineral fertilizers. The pictures show something in addition, and that is, that the manure helped the clover immediately and some time before the minerals helped it. Therfore if the green weight had been taken earlier, the difference would have been greater. With all this evidence it is certain that manure has some constituent that helps the growth of clover, other than the nitrogen, potassium and phosphorus found in it.

The question now is, what is this constituent of manure? It has been shown that the manure did not correct acidity of the soil, that the physical effect of the manure is not a help to the clover, and further, that it was not on account of the bacteriological relations. There seems to be only two possible explanations left. One is that the soluble organic matter in the manure is used as such directly by the clover plant for nourishment, without first being broken down and then assimilated in simple forms. The second is that there is a poison in the soil and that the manure neutralizes it. The one is the toxin theory, the other the soluble plant food theory. At this time the plant food question will be discussed, leaving the other to be considered by itself.

There have been a few investigations that throw some light on the question of the ability of plants to use organic matter as food. L. Lutz has reported considerable work in Bulletin de la Societe Botanique de France. Abstracts of these papers have appeared in the Experiment Station Record from time to time.[1]

Lutz has found that various nitrogen compounds can be assimilated directly by plants. He has done a vast amount of experimenting, using flowering plants, algæ, fungi and molds, and has tested them with a great number of nitrogenous compounds. He uses a sterile medium, sand or similar culture, and for each kind of plant the only source of nitrogen was to be found in the compound under investigation. Experiments are reported with cucurbit seedlings, in solutions containing leucin and tyrosin as the only sources of nitrogen. Where leucin was added to the culture medium, gains of 35.8 per cent to 40.8 per cent in nitrogen are reported, while for tyrosin a gain of 11.9 per cent is given. Leucin being more soluable is much better assimilated than tyrosin. Leucin contains the radicle NH_2. It occurs in different animal fluids and is physiologically very important. It is formed by the decay of albuminoids and is soluble in 48 part of water. Tyrosin is quite similar.

The results, the author claims, have a practical bearing in the practice of composting. In this way the frequently rapid action of manures may be explained. The author believes it is practically demonstrated that many organic nitrogenous substances are directly assimilated by plants, and the common belief that ammoniacal fermentation takes place first, followed by nitric fermentation, is not in accord with what actually occurs in the plant.

What about the assimilation of carbohydrates by plants? M. Molliard[2] of France experimented with radishes, one lot being grown in mineral solutions, the other in various forms of carbohydrates. When grown in solutions of saccharose, glocuse, levulose, dextrin, etc., the color, size, form and structure of the leaves were greatly modified. The plants were able to make considerable growth, utilizing the carbohydrates through their roots.

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[1]Exp. Sta. Rec. XVIII, p. 348. This gives previous references.
[2]Exp. Sta. Rec. XVIII, pp. 25 and 127.

Geo. F. Atkinson[3] in the bulletin, "The influence of mushrooms on the growth of some plants," gives a valuable contribution to the question of the ability of plants to use soluble organic matter directly as food. The author first proves that mushrooms are available for food for several green plants, both when fermented and when unfermented. These were not tested under sterile conditions and the unfermented had a chance to ferment, and therefore it is not certain that the organic compounds were used unchanged.

He next grew radish and cabbage in pure cultures with agar as a substratum, and he found that both the fermented and the unfermented mushroom material caused some growth of the plants, although not quite so much as that caused by the nutrient solution. We quote: "These pure cultures show that for the radish and cabbage there is plant food for autotrophs in an unfermented infusion of the common mushrooms, for they grew to a larger size here than in distilled water. The unfermented mushroom, however, does not offer so good a nutrient as the products of fermentation do, and this is not surprising, although it is a little surprising that the unfermented mushroom can serve as a nutrient for autotropic green plants. Mendel has shown, however, that a considerable part of the nitrogen in mushrooms probably exists as non-proteid nitrogen, some in the form of cellulose nitrogen and some in a form that can be extracted with alcohol. The former probably becomes available in the fermented mushroom, while the latter is directly available in the infusion of the unfermented mushrooms." The author thinks the evidence conclusive that the plants used the nitrogen directly as it was found in the mushrooms without its being changed into the nitrate or ammonia form. This is undoubtedly true if it is certain that the only way organic compounds of nitrogen can be converted into the ammonia or nitrate form is through the action of bacteria. This point has been considered settled by bacteriologists. The only other explanation is that the organic substances were changed by the direct oxidizing action of the roots of the plants themselves. There is very little evidence to support this view, however, and it seems probable that in this case soluble organic matter was used directly as plant food.

One more reference will be given. It is to the article of J. Lefevre[4], entitled, "The development of chlorophyllous plants in the absence of carbon dioxid, but with non-toxic quantities of amids." A series of experiments were conducted with cress and sweet basil grown in pots under bell jars without carbon dioxid, but in the presence of a number of amids. The plants were supplied with chemical fertilizers to which was added a mixture of tyrosin, oxamid, glycocoll, alanin, and leucin at the rate of 1.1 g. for every 500 g. of soil. The plants were observed under conditions of light and darkness, and it was found that in the presence of sunlight they were able to make considerable growth, attaining in six weeks a size fully ten times that of the original, and with well developed foliage and flower buds. As this growth took place in the entire absence of carbon dioxid, the carbon required must have come from the amids and was taken up by the roots. That the transfer was not simply osmotic, but true synthesis, is shown by the absence of all, or nearly all, growth when the plants were kept in the dark. Apparently photosynthesis took place in almost normal amount.

But if it is admitted that plants can, under certin conditions, use organic substances directly as food, it has not been shown how general the practice is.

[3]Cornell, N. Y., Exp. Sta. Bull. 240.
[4]Exp. Sta. Rec. 19, p. 22.

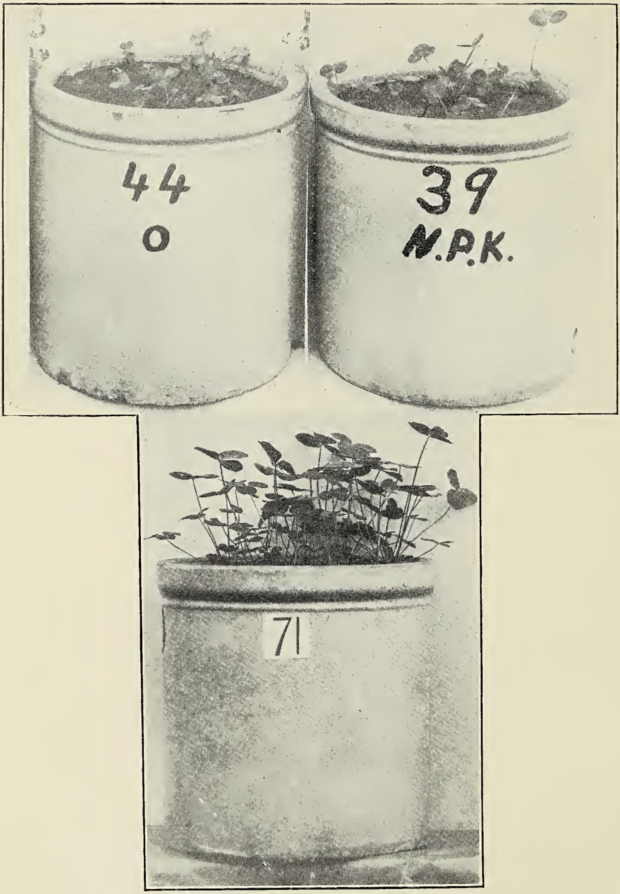

Plate VI. Effect of drying the soil.

It by no means proves that the manure nourished the clover in the case under investigation directly by its soluble organic matter.

But why should it seem strange that flowering plants should be able to assimilate soluble organic matter as such and use it directly? We are still slaves to Liebig's mineral theory. Plants undoubtedly can be brought to perfection on mineral food alone, but this is not saying that they could not use other food. In fact many plants do use organic food. The non-chlorophyl humus plants subsist on organic food, and if they can, why is it not possible for chlorophyl plants to do so? In fact some of them do. The mistletoe uses elaborated food. The carniverous plants, as the sundew and the pitcher plant, growing on the northern bogs use insects as food. The sundew captures and digests insects on its leaves and these help it to grow better and produce more and better seeds. The pitcher plant also is helped by the insects that it entraps and digests.

This investigation of the plant food problem has brought out the following points: it has proved that manure has a beneficial action other than that attributable to the soluble mineral plant food found in it, and this beneficial principle is not lost by boiling the liquid manure. It has been shown by scientific investigators that plants under certain conditions can directly assimilate many soluble nitrogen compounds, and also certain carbohydrates.

The evidence is far from being conclusive that in the case of the clover in question the soluble organic compounds of the manure were used directly as food. It is not proved, but enough evidence has been submitted to keep the question open.

THE ANTITOXIC ACTION OF THE MANURE.

The Bureau of Soils has advanced a theory in regard to the cause of unproductive or worn-out soils, which is well stated in the following extract.[5] "Infertility is often due to the presence of toxic organic bodies in the soil, either excreted by the previous crops or perhaps formed by the action of bacteria, molds, or ferments from the plant remains. These toxic bodies are organic. They may be fatty bodies, nitrogenous bodies, or non-nitrogenous. They appear to be quite unstable in the soil, changing rather easily by oxidation into harmless or even into beneficial bodies. They are not equally harmful to all plants."

There were many things in connection with this investigation that suggested a toxin in the soil as the cause of the poor growth of the clover, and for this reason the toxin theory was given as thorough an investigation as the circumstances permitted. One of the occurrences that supported the theory was the fact that the soil when kept in the greenhouse gradually changed in its attitude towards the growth of clover. As evidence of this, the following pictures are submitted:

Pots 44 and 39 were planted soon after the soil came to the greenhouse and the pictures were taken sixty-five days after the series was planted. Pot 71 was filled from the same sample of soil that had been kept in the greenhouse and allowed to dry for nearly three months. The picture was taken sixty-nine days after planting, therefore it is only four days older than pot 44, but there is a remarkable difference in the growth. A change has undoubtedly taken place in the soil and the most probable explanation is that some harmful substance that was hindering the growth of the clover in the first place, has dis-

[5]Bulletin 55, Bureau of Soils, p. 64.

appeared and has allowed the clover to grow in a normal manner. The only other explanation is that the plant food has become more available, but this is easily disproved. Pot 39 received soluble plant food in abundance, undoubtedly having a great deal more than pot 71 could have, but pot 39 is only a shade better than pot 44 and not nearly up to pot 71. Therefore it is not a plant food question. This was not an isolated case, but the same occurrence happened several times. The soil, when allowed to lie in the greenhouse and dry for several months, invariably became much better suited for the growth of clover. This certainly suggests the presence of a toxin in the soil.

The methods pursued by the Bureau of Soils to determine the presence of a toxin were not applicable in this case, for clover does not submit to the special treatment required, namely, growing in water cultures in bottles. An approach to their methods was made by proceeding as follows: Soil sufficient to fill a pot was spread out one inch deep in a large sieve over which a piece of muslin had been spread. Water was leached through this until twice the weight of the soil had run through. The soil was then dried until it came to optimum water content, carefully worked and treated for several days to destroy any lumps, and then packed into the pot. The leached water was applied to the soil for another pot. This was allowed to dry and was then put into optimum physical condition and packed into the pot. It would seem that if this soil contained a soluble poisonous substance that retarded the growth of the clover, that the soil would be better for washing. It would also seem that if this extract containing the toxin were transferred to another sample of this soil, that it would be there concentrated and still further hinder the growth of the clover. Of course, this extract will carry other things beside the toxin, among which is considerable plant food, but if the toxin overbalances the effect of these things in the original soil, why would it not have the same effect when applied to a new pot of soil?

In the following series, pot 224 was filled with soil which had been leached, and this leaching, or extract, was added to the soil in pot 222. In the same way the leaching from pot 225 was added to pot 223. The series was planted October 19, 1906, and it was harvested ninety-one days later. The data secured is here given.

TOXIN EXTRACT SERIES

Pot	Treatment	Green weight g	No. plants	Relative weight	Average
200	Check	4.1	10	96	
201	Check	4.4	10	103	100
222	Extract added	4.0	10	94	
223	Extract added	5.9	10	139	116
224	Leached	5.45	10	128	
225	Leached	4.9	10	113	120

The data shows that the pots which were leached have an average gain of 20 per cent, showing benefit from the process. But the effect of adding the extract to the soil is uncertain. One of the pots shows a slight decrease in the growth of the clover, and the other one a large gain. Therefore it cannot be claimed that the presence of a toxin was proved by the experiment, but the results certainly suggest that there was a toxin in the soil. Undoubtedly the method is crude, and it is not certain that reliable results could be obtained by it, no matter how large the number of duplicates.

The problem was attacked from another side by using an entirely different medium in which to grow the clover. Quartz sand was used. This was absolutely neutral and non-toxic. With it as a substratum, eliminating the factor of the soil, the action of the manure was seen directly, and it was not complicated by appearing in connection with the action of the soil.

For this experiment a medium grade of quartz sand was used. The sand was prepared by placing it in pots with drainage outlets, digesting it with a 10 per cent solution of sulfuric acid, and washing the acid out with tap water until the sand was neutral in reaction. The tap water was then washed out with distilled water and the sand dried. It was dried in order that the net weight of the sand going into the pots could be known, and the pots be kept at the optimum water content. Gallon pots were used with the outlets stopped. 4,700 grams of the dry sand were placed in each pot. One gram of c.p. calcium carbonate was added to the sand in each pot to prevent any possible acidity. Enough distilled water was added to bring the sand to 15 per cent water content, as this seemed to be its optimum. Distilled water was used throughout in watering the series. By weighing at any time the per cent of water in the sand could be known and water added to supply the evaporation.

The nutrient solution used was the standard one used in the laboratories of the Iowa State College. The following comparisons shows the elements of fertility found in it and in the sample of manure leachings with which it is compared.

Elements	Nutrient solution, g. per L	Manure leachings, g. per L
N	11.2	.470
P	2.	.093
K	2.	1.060

Five c.c. of the nutrient solution was used per pot on those treated with mineral plant food. 117.5 c.c. of the manure leachings were applied to each pot treated with manure. This amount of leachings contained the same amount of N and P as 5 c.c. of the nutrient solution, but considerably more K. The series was planted July 25, 1907, and the clover sprouted uniformly and grew off without any check.

The treatment of the series is shown in the following table which also gives the notes taken on September 6th, and the final weights and notes made October 10th.

SAND SERIES, PLANTED JULY 25, 1907.

Pot	Treatment	Notes Sept. 6		Weights and notes Oct. 10				
		No. of plants	Height inches	No. of plants	Height inches	Weight of tops g	Weight of roots g	Root nodules
507	Check	9	.87	7	1.	.2	.14	None
508	Check	10	.75	7	.75	.2	.12	None
509	Check	10	1.00	10	1.25	.5	.17	None
510	Manured	10	1.25	3	.75	.1	.10	Few
511	Manured	3	1.12					
512	Manured	9	1.75	5	2.	.7	.20	Few
513	Nut. Sol.	8	1.25					
514	Nut. Sol.	10	5.00	10	8.00	15.2	3.10	Abundant
515	Nut. Sol.	10	5.00	10	7.50	15.3	3.40	Abundant

All the plants were inoculated with the clover bacteria on August 6th. On August 10th all the pots had a stand of from fifteen to twenty plants, and they were thinned down to ten plants per pot. The plants in all the pots were healthy and on a par.

By August 23d, pot 513 began to look unthrifty. The leaves lacked chlorophyl and the plants soon began to drop behind the others, and in another month they were all dead. There was considerable growth of algæ over the surface of the sand. Under the microscope this was seen to be an unicellular plant gathered together in clusters. The species was not determined. This pot was very evidently diseased, and it is taken out of the reckoning.

By August 23d the manured pots began to drop behind the pots treated with the nutrient solution, and they were given the second application of 117.5 c. c. of manure leachings to each pot. 5 c. c. of the nutrient solution, diluted to 117.5 c. c. were also given at this time to the pots that had received this treatment at the beginning. Three days later it was seen that several of the plants in the pots treated with manure leachings were suffering from the application last given. They were watered to dilute the toxin as much as possible. By September 18th all the plants on pot 511 were dead. Over half the plants on the other manured pots also died before the end of the experiment.

It is seen by studying the data given above that the clover in all the pots started off together and grew well, showing that the sand was a good medium in which to grow the clover. This also disposes of the question of any ill effects arising from the toxins thrown off by the germinating clover. Any such toxin was in such minute quantities that it did not affect the growth of the clover. The check pots show this. The clover on these pots made a normal growth for the first four weeks, after which it grew but little, but most of it lived until the end of the experiment, which ran eleven weeks.

The manured clover at the end of six weeks showed only a slight gain over the checks. This gain showed that the manure did furnish some plant food to the clover, but it was very little. The manure was evidently poisoning the clover, for one-fourth of the plants were dead at this time, and three-fourths of them were dead at the end of the experiment. Considering the condition of the clover at the close of the experiment, it is seen that only a few of the manured plants received any benefit from the manure, and they only to a slight extent.

In striking contrast to the behavior of the manured plants, were the plants fed by the nutrient solution. These grew without any check, in a normal manner, showing perfect nourishment, leaving out of consideration the diseased pot. At the end of six weeks they were four times as big as the manured plants, and at the end of the experiment the weight of the tops per plant was over ten times that of the manured plants, and the weight of the roots eight times as much.

In brief, the nutrient solution was a good plant food under these conditions, and the manure by itself was not. It might be thought as an explanation of its lack of feeding power for the clover, that the proper bacteriological changes did not take place in the manure extract because the sand differed so from the soil. There are two answers to this: In the first place the sand was not kept sterile, but was at all times open to inoculation from the air and the dust of the room. The sand was also inoculated with a soil extract as noted, and it had every chance to become filled with soil bacteria. In the second place, the work on the bacteriological relations of the manure, elsewhere reported, reached this conclusion. "Bacteria are in no way responsible for the beneficial action of the manure on the growth of the clover, for in the first place it was shown that sterile manure was as beneficial as the unsterilized, and in the second place it was shown that when the whole pot was sterilized the crop did not suffer, but was even a little better." Therefore it was not on account of the bacteriological relations that the manure did not nourish the clover when grown in the sand.

The following points are proven: 500 c. c. of manure leachings when applied to a pot of the soil under study, caused a remarkable growth of the clover during the first two months of its life. The nutrient solution when applied to this soil helped the clover finally, but the help was very tardy in coming. 235 c. c. of the manure extract (in two portions) when applied to the same sized pot containing an equal number of clover plants, but filled with the quartz sand. failed to feed the clover, but on the contrary poisoned it. The nutrient solution in this same sand caused a perfect normal growth.

The problem of the action of the manure on the soil has been narrowed down to the plant food or the antitoxic action of the manure. By taking the manure and the clover away from the soil and placing them in this neutral sand, it is easy to see how the manure affects the clover. If the manure fed the clover in the soil it should do the same in the sand. If the soluble organic matter in the manure was used directly by the clover and was better suited to it than mineral food, then the plants fed by the manure should have surpassed the plants fed by the mineral food when they were both grown in the sand. The failure to do so proves that the clover does not use the soluble organic matter as food, and the remarkable growth of the clover treated with manure when grown in the soil is not due to the plant food found in the manure.

Looking at the question from the side of the soil, the theory that the soil experimented with was a poor medium for the growth of clover simply for the lack of readily available plant food, and that the manure supplied this, is untrue. The sand experiment showed that the nutrient solution was a good plant food, but when this was applied to the soil the help it gave the clover plant was very tardy. On the other hand the manure is shown not to be a good plant food by itself, but when applied to the soil the benefit received from it was immediate and striking.

The only explanation left for the action of the manure on the soil, is the toxin theory. There were toxins in the soil which were neutralized by the manure and this purified the soil, making it a good medium for the growth of clover. When the clover was grown in the sand, no toxins being present to neutralize, the antitoxin in the manure was an injury to the clover. The soil pots that were treated with mineral fertilizers apparently had the toxins corrected by the combined action of the clover roots and the chemicals, but this was a slower process than the action of the manure. That this action can take place has been demonstrated by the work of the Bureau of Soils.[1]

THE TOXIC ACTION OF COCKLEBURS.

The previous study has shown that there is a toxin in the soil which is being investigated. This toxin may have arisen from various sources and it is possible that it may have come from some of the weeds which grew in the

[1]Bull. 47, Beureau of Soils, U. S. Dept. Agri.

field. In considering the matter, suspicion fell at once on the cockleburs, xanthium canadense. The experiment field was very foul with this pest when the station secured it, and it was noticed that the soil secured the first year showed more toxic effect than that secured the second year, either in the greenhouse or in the field. This might have been due to the clean culture given the field as soon as it came under the management of the station.

Henry Wallace[2] reports that the idea of the toxic action of weeds came to him in a conversation with the celebrated Sir John B. Lawes. When looking over his famous experimental plots at Rothamstead, England, he showed Mr. Wallace a field of wheat that had been in continuous cultivation without manuring for forty-five years, with a gradual decreasing yield. It had, however, been carefully hand weeded; and Sir John made this remark: "We must get rid of weeds. Weeds poison the land."

That the bur is poisonous to animals is known. Mayo[3] states that the common cocklebur seems to cause poison only in its early two-leaf stage, when the cotyledons are well developed. Animals never eat the unsprouted burs for very evident reasons. He mentions cases where it seems that the burs had killed quite a number of hogs. Nobody has isolated and studied this poison. The poisonous principle of another species of cocklebur, X. strumarium, was investigated by A. Zander[4], a German investigator, in 1881. He isolated the poisonous principle and named it zanthostrumarin. No formula or classification was given for the poison. If the cocklebur contains a substance that is poisonous to animals, why should not this substance be poisonous to plants? The living cells of animals and plants are very similar and respond to stimuli in nearly the same manner. They are affected by the same poisons and differ only in degree of susceptibility.

With a view of investigating the production of a toxin in the soil by cockleburs, five samples of soil were secured from the field in October, 1906, so that soil which had suffered different treatments could be compared. These samples were pulverized as soon as they reached the laboratory and placed in closed cans to prevent drying, in order to keep them as near field condition as possible.

A sample was taken from plot 101 to be as near as possible like the samples secured the previous year. This was in clover at the time the sample was secured, and had been in oats and clover the year previous. The clover was a thin stand.

Samples were secured from plots 113 and 213. These were new plots added in the spring of 1906. Plot 113 was sown to cowpeas in June but they had proved a failure. Plot 213 was in oats and clover. The oats yielded 7.5 bushels per acre and the clover was a failure. They both raised a very light crop of beans the previous year, were left rough and lumpy, and were very foul with cockleburs and horse nettles.

A sample was secured from plot 208. This had the same crop and treatment during 1906 as 213, but the oats yielded 23.1 bushels. The clover was practically a failure. The crop in 1905 was corn which had been kept free from weeds.

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[2]See Wallaces' Farmer of June 7, 1907.

[3]Proc. Am. Vet. Med. Assn., 1902, p. 194.

[4]Dictionary of the Active Principle of Plants. Sohn.

A sample was also secured from plot 308. This had been in corn both years, was free from weeds and was in good tilth.

None of these plots had received any manurial treatment. They were all check plots and differed only in crop and cultural treatments.

Cockleburs were supplied to two of these soils. They were freshly gathered burs, ground and added to the soil at the rate of 19 grams per pot, which is .5 per cent of the weight of the soil in the pot. The percentage of burs which might occur in the soil under field conditions is estimated at .2 per cent. The burs from one medium sized plant were found to weigh 70 grams. This plant occupied about two square feet of space, and at this rate the crop would be 3,361 pounds per acre. When we take into consideration that the leaves and the stalks also fall on the soil, and that there are residues of previous crops, for the burs are very slow in decaying, it is not hard to believe that two tons is a fair estimate for a bur crop. A good crop of corn, including the stalks, is three or four tons per acre. Two tons incorporated in the top six inches of the soil is .2 per cent. Therefore the burs were supplied in the pots approximately twice as heavily as they would be in the field.

The 19 grams of burs contained 1.74 per cent of nitrogen, or .36 grams. They contained .4 per cent of phosphorus, or .076 grams. The potassium was not determined, but as in all the previous experiments it has not proved a contributing factor in the growth of clover, the exact amount present was not material. The manure leachings had .2 grams of nitrogen and .0456 grams of phosphorus. Therefore the burs contained nearly twice the amount of plant food that the manure did.

A series of pots from these samples was planted October 19, 1906. Final weights were secured January 18, 1907, or ninety-one days after planting. The series of the different soils with the treatments and the results are given in the following table.

OCTOBER BUR SERIES.

No. pot	Soil plot	Treatment	Green weight	No. plants	Wt. per plant g	Relative weight	Average
200	113	Check	4.1	10	.41	96	
201	113	Check	4.4	10	.44	103	100
202	113	Manure leachings	7.9	10	.79	186	
203	113	Manure leachings	9.5	10	.95	223	205
242	113	Cockleburs .5%	4.15	7	.593	140	
243	113	Cockleburs .5%	4.8	6	.80	188	164
226	101	Check	6.2	10	.62	146	
227	101	Check	6.15	10	.615	145	145
230	208	Check	4.4	10	.44	103	
231	208	Check	6.0	10	.60	141	122
234	213	Check	3.0	8	.375	90	
235	213	Check	4.9	10	.49	113	102
236	213	Cockleburs .5%	5.35	9	.593	140	
237	213	Cockleburs .5%	5.4	10	.54	127	33
238	308	Check	4.95	10	.495	116	
239	308	Check	5.1	10	.51	120	118

The data given above contains considerable support to the theory that the burs grown the year previous had left a toxin in the soil, and that the burs when added to the soil also poisoned it. The soil from plots 113 and 213 which had run to burs in 1905 and grew practically no crop in 1906, were on a par for clover growing. Taking these as a standard, the soil from plot 101, which had been kept free from burs for two years, was in oats the first year and a thin stand of clover the second year, was 45 per cent better for clover growing. The soil from plot 208, given clean culture, corn the first year and oats the second, was 22 per cent better. The soil from plot 308, given clean culture and in corn both years, was 18 per cent better.

The burs in one soil produced a gain of 64 per cent. In this case the stand was light and as the gain was calculated per plant, it gave the burs an advantage. In the other soil the gain was 33 per cent. This shows that the burs did nourish the clover, but not to the full extent of the plant food found in them. They had practically twice the plant food that the manure had, but the gain was much smaller than that produced by the manure, which was 105 per cent. Either the plant food in the burs was not available, or the burs contained a poison which counteracted much of the plant food action of the material.

This pot method is somewhat crude and results obtained from it are not entirely satisfactory. The trouble is partly that results are based on weights of clover several months old. The burs are decidedly toxic to clover at germinating time, but after the plant is once started, the bur has a much smaller effect on it. Field observations established the fact that clover and cockleburs may grow side by side, if not in harmony, at least with tolerance.

The effect of the burs on the germinating clover is shown by the following notes: On October 25th it was noted in the series just described that the clover was coming very good and fairly even in all pots except in 236 and 237, which had none sprouted, and in 242 and 243 which had six and five respectively. These pots were the ones treated with cockleburs. Pots 236 and 237 were replanted with ten seeds each. This was six days after the clover was first planted. Five days later, pots 242 and 243 had several plants each which had come through the soil but the cotyledons ware burnt off. Three days later all these pots treated with burs had additional seeds planted in them to supply the lack of stand.

In spite of this extra seeding it is seen by the table that only one of the four pots had a full stand. Just about one-fourth of the seeds planted in the pots treated with .5 per cent of burs succeeded in producing clover plants. In the other pots, from 90 per cent to 95 per cent of the seeds produced vigorous plants. The burs undoubtedly hindered the germination of the clover by poisoning it.

The nature of the poison in the burs was not ascertained. They were tested for alkaloids but none were found.

Work in physiological chemistry during the last two decades has been characterized by a thorough and systematic study of solutions from both the theoretical and experimental points of view. The discoveries made in this work have been a great help in giving an insight into some of the problems of plant physiology. A wide field of research along physiological lines opened up by applying to the field of biology the dissociation theory that has proved so fertile in chemistry and physics. A desire for a deeper and clearer insight into the subject of the nutrition of plants has lead many botanical investigators to study the poisonous or stimulative qualities of a large number of compounds. The literature on this subject is very large. These men have developed a method of research, which, although the matter of detail varies considerably, in the main features may be briefly described as follows: Seeds of the plant which it is decided to use are germinated, and when the radicles are a few mm. long they are placed in the solution to be tested, and the effect of the solution on the growth and vitality of the radicles is noted. It is not a question of nutrition and no plant food problem can be attacked in this way. The radicle is fed by the store of plant food in the seed, and any effect which a solution may have is due to injury or, it may be, stimulation. The radicles are extremely sensitive and this makes it a very delicate test. The ordinary distilled water of our laboratories is entirely unfit for use in these investigations and especial precautions are always taken to get non-toxic water. This shows the delicacy of the method.

The presence of a toxin in the burs was tested by this method which may be called the Plant Radicle Method. Corn was first used as an indicator. 15 g. of dry burs were ground as fine as possible, placed in a small cloth sack, boiled in distilled water, and the extract thus obtained brought to 100 c. c. This extract contained 1.35 per cent solid matter and is designated in the following tables as ext. N. Diluted to twice this volume it is called N—2, etc. No mold would grow on this extract. either N strength or N—2 strength, even when inoculated with mold. This shows that it was toxic to mold.

The corn seedlings used were germinated between sheets of filter paper and the moisture supplied by wet sphagnum moss above and below these sheets. Fresh sheets were used each time to avoid mold. Seedlings that developed normally and with straight radicles were used. The test was made in test tubes of various sizes, all the tubes of one series, however, being of a size. A cork was made to fit the tube, the radicle of the seedling was passed through a hole in the cork and into the liquid to be tested, which filled the tube up to the cork. The length of the radicle was marked on the outside of the tube by a blue pencil. The seedlings were allowed to remain in this position for twenty-four hours and the growth if any was measured by holding the tube up before the eye and measuring from the blue mark to the end of the radicle. This could be very easily and accurately done. The solution was then emptied, the tube cleaned carefully, filled with distilled water, the seedling rinsed and replaced, and the position of the end of the radicle marked on the glass. In twenty-four hours the growth was again noted. This second day's growth in distilled water was to determine the condition of the radicle. If no elongation took place it was dead. If it was as long as the check it was uninjured. If the elongation was less than the check it was injured, and the degree of injury could be very accurately judged by noting the amount of retardation. Observations confined to the first day are not conclusive. The best and most practical test for vitality is the ability to grow when taken out of the toxic solution and placed in distilled water. The above method is a slight modification of that used by Loew and Dandeno, which seems to be the best and most convenient of all the methods given.[r]

TOXICITY OF COCKLEBURS.

July 20, 1907. 5 c. c. test tubes used. Growth in mm.

	Ext N		Ext N-2		Ext N-4		Check	
	1	2	1	2	1	2	1	2
Ist day, extract	0	0	0	2	11	5	28	40
2d day, distilled water	0	0	0	0	17	20	30	38

August 1, 1907.

	Ext N-8		Ext N-16				Check	
	1	2	1	2			1	2
1st day, extract	21	18	11	12	--------	--------	58	36
2d day, distilled water	26	26	23	27	--------	--------	52	30

This data shows that the extract of normal and half normal strength was violently poison, and the N—4 strength quite so. Considerable of the poisonous effect still remained even when diluted to 1-16 of its original strength. As this would bring it down to .08 per cent solid matter in the extract it could not be a question of osmosis or even of the toxicity of nutritive salts in the extract.

The toxicity of the burs for clover was also tested by using the following modification: Clover seed was sprouted in a large watch glass in tap water which was changed once a day. When they were well sprouted, seeds were chosen with radicles 5 mm. long and these were transferred to 5 c. c. of the solution to be tested, which was placed in a watch glass and the whole covered with an evaporating dish to prevent evaporation. The length of the radicles was recorded at intervals in mm. The results were as follows:

TOXICITY OF COCKLEBURS FOR CLOVER.

	Ext N			Ext N-2			Ext N-4			Check		
July 23.	1	2	3	1	2	3	1	2	3	1	2	3
Length at start	5	5	5	5	5	5	5	5	5	5	5	5
Length July 24	5	5	5	10	8	7	7	6	5	10	9	8
Length July 25	*	*	*	13	10	7	8	7	5	12	12	10
Length July 26	-----	-----	-----	13	10	7	8	7	5	14	14	11
Length July 29	-----	-----	-----	†	†	*	*	*	*	32	32	25

	Ext N-4			Ext N-8			Ext N-16			Check					
July 31.	1	2	3	1	2	3	1	2	3	1	2	3	4	5	6
Length at start	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Length August 2	14	11	9	20	14	12	16	12	9	14	15	14	19	19	13
Length August 5	25	15	*	36	20	18	40	22	*	28	23	21	17	25	25

[1]F. A. Loew. The toxic effect of H and OH ions on seedlings of Indian corn. Science II 18, pp. 304-308, 1903.

Dandeno. Relation of mass action to toxicity. Am. Jour. Sci. IV, 17, p. 437, 1904.

*Dead.

†Alive.

The first trial shows that the bur extract was poisonous to clover, even the one-fourth strength entirely killing the clover. In the second trial the results are somewhat erratic. The N—4 strength killed only one of the plants, and the N—8 and N—16 dilutions were actually stimulating to two of the plants. Still even in the weakest dilution one of the plants was killed, showing toxicity. The clover is not quite as susceptible to the toxin in the burs as the corn.

From the trials with the corn and the clover the general conclusion can be drawn that there is a substance in the cocklebur which can be extracted with hot water, which is poisonous to them both. Calculations show that the extract from 15-16 of a bur was found in each 5 c. c. of the N—4 extract, and that 9 per cent of the bur had been extracted. Therefore there was enough poison in one bur to seriously poison the corn or clover radicle in one day.

Work had to stop at this point, but the following facts were proven: There is a toxin in the burs, and a sure, easy, and delicate method was found for detecting this toxin. This toxin is not only poisonous to corn and clover when the radicles of these plants is immersed in a water solution of the toxin, but it is also poisonous to germinating clover when growing in the soil. The pot cultures also give strong indications that the presence of the burs in the soil is detrimental to the growing clover.

SUMMARY.

The Southern Iowa loess from a certain field was studied in the laboratory to ascertain the reason that stable manure caused the remarkable increase in productiveness which it did when applied to the soil.

It was found that the soil was not acid.

The physical effect of the manure on the soil was not responsible for the better growth of the crop.

Bacteria were in no way responsible for the beneficial action of the manure on the growth of the crop.

The investigation of the plant food brought by the manure proved that the manure had a beneficial action other than that attributable to the soluble mineral plant food found in it. Evidence was brought to support the theory that the clover used the soluble organic matter directly as food, but this point was not proven.

The study of the antitoxic action of the manure showed that this was the only explanation for the action of the manure on the soil. There was a toxin in the soil which was neutralized by the manure. The soil pots treated with mineral fertilizers had the toxin corrected by the combined action of the clover roots and the chemicals, but this was a slower process than the action of the manure.

A study of the cockleburs which grew abundantly on this field, showed that there was a toxin in the burs which was fatal to both corn and clover. The inference is natural that the burs caused the toxicity of the soil.

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THE OKOBOJI LAKESIDE LABORATORY.

BY THOMAS H. MACBRIDE.

The establishment of the Okoboji Lakeside Laboratory, founded by the alumni of the State University of Iowa, promises to affect so deeply the future scientific work of our state that some account of its beginning and especially its *raison d'etre* may rightly claim the attention of the Academy. The laboratory has been located on the west shore of Lake Okoboji in Dickinson county for the reasons following:

In the first place the topography of Dickinson county is peculiar, unique. Situated on the western border of the Iowa Wisconsin drift, the region illustrates, as possibly no other equal area in the state, the special characteristics, not only of glacial moraines in general, but in particular the very expression of the Wisconsin moraine. In fact, I think that it must be admitted that the Okoboji lakes and their encompassing hills do indeed form the finest bit of morainic topography to be found on our western prairie.*

This fact, of course, makes the locality an especially interesting field for illustrating to the student all the fascinating features of the latest page in the geologic history of our state. Indeed, the very fact that the locality is marginal makes it especially interesting, and studies of contact, of movement and retreat, as well as of direction and relation to pre-existing topography—all these things are especially accessible and patent within half a day's drive along any highway south or west.

Secondly, the region having Okoboji for its center is, by reason of the peculiar topography just mentioned, the field of a special floral display difficult to illustrate anywhere else within such narrow limits. We have a forest flora and a prairie flora; and neither in this part of the world has ever been adequately studied. It is believed that the fungal flora of the region, for instance, is especially rich and interesting. We have all kinds of habitat conditions, from aquatic to xerophytic. We have deep water, shallow water, but permanent; marshes, springs; and zerophytic slopes and hill-tops, some so dry as to offer home to the vegetation of the higher western semi-arid plains. The plankton of the lakes is filled with desmids and diatoms and all manner of algal flora, during July and August rich beyond comparison in all that makes up the tide of life for these simple but fascinating forms.

Neither have the xerophytes been studied nor the flora which joins these, perchance, in ecologic bonds with their aquatic congeners, for the waters are filled with flowering plants, richly indeed as with floating cryptogams, and the factors of ecology and distribution all are here, in large part so far, unexplored and certain to interest for centuries generation after generation of Iowa students.

*It is here assumed that the Okoboji hills are morainic: further exploration may offer another explanation.

For similar reasons, the fauna of the lake district will reward our constant study. The varied flora, just described, insures a varied fauna. The waters teem with animal life. Probably the protozoa of the whole valley will be found hiding on the vegetation of these quite lakes and pools. Of course, the avian and vertebrate aquatic fauna are rich, and even the terrestrial vertebrates are likely to prove more than commonly worthy of investigation. While this is writing the papers tell of a mountain lion shot in one of the near-by marshy lakes! It is not believed that carnivores of size are likely to abound, not to such extent at least as to warrant a future visit from our nimrodic ex-president, but it is believed that natural science, in all its branches, entomology, ostracology, ornithology, will be greatly enriched by using such opportunity for research as Okoboji may afford.

Again, Okoboji as the world knows is already a place of resort, thousands of people find summer habitation on its shores. So that we find here unequalled opportunity for bringing scientific work to the attention of people of every class and kind, and confessedly natural history work in all our schools, colleges and universities is too formal, too artificial, too much based upon material specially prepared, laid up in herbaria, or conserved in cases and bottles; the lakeside laboratory offers an opportunity to correct this, at least in some small measure. Ever since the immortal Agassiz stood bareheaded with that famous company on the rocks of Pennikese, the naturalists of the world, at least, have realized that the proper and reverent place for the study of natural objects is in their natural surroundings. Dry dead fungi are dusty labelled things, as meaningless as the stuffed skin of mammal or bird, or a fossil in a box; better than no exhibit at all, to be sure, but poor indeed as compared with the natural world, where the fungus starts in the forest shade, the wings of bird or insect fan the sunny air, or the fossil speaks its significance from the stony pages of the riven quarry stone. The lakeside laboratory shall afford to all interested, for once at least a chance to see the real world, nature alive, accomplishing her miracles in their own silent splendor, often needing not, for the student's appreciation, the voice of interpreter or teacher.

A few words now may describe the provisions making for natural history work. The university alumni have purchased property for a plant. About five acres of ground with a cottage for administration purposes, a boat-house, pier, and so forth, are already the equipment. It is expected within the next few days to erect a building for laboratory uses. This building will offer office, library and laboratory for each professor in charge of a line of work. A large hall to seat 125 people comfortably will be accessible for general lectures, evening entertainments, and so forth, and from the university such apparatus will be supplied as to enable ordinary classes to work successfully in botany, geology and zoology. Boats and dredges also will be at hand, while public conveyances enable students to reach conveniently more distant points of interest. It is proposed to offer tents and cottages to all comers up to the limits of laboratory accommodations; at present a class of not more than thirty is in contemplation; and simple meals will be obtainable at reasonable rates.

The classes sought to be accommodated are; first, all students of nature competent to enjoy the laboratory method of instruction; the laboratory shall be open to anybody capable of using its privileges; second, teachers of biologic subjects in academies and high schools everywhere, who may desire to combine recreation with work and who may find in the service of the laboratory occasion to acquaint themselves with Iowa conditions and thus better equip themselves for serving the children of the schools; third, graduate students who may desire to perfect themselves in some line of research preparatory or introductory to an advanced degree. Such students are presumably competent to conduct work for themselves, needing simply a place at table and such suggestions as occasion may develop.

In general, however, the laboratories for use are to be open to the world, students enrolling in the order in which application arrives. It is hoped that the open door may be thronged and that the enterprise may not only serve those already engaged in scientific work, but may reach and influence thousands and make real all natural science to the upbuilding and quickening of every school, college or academy within the borders of our state.

SOME FEATURES OF IOWA GROUND WATERS, II.

BY W. S. HENDRIXSON.

About two years ago the writer read before this body a paper, under the above title, giving a general statement of his work on the quality of Iowa well waters. The accumulating experience of the past two years seems to justify at this time a statement of some additional facts that seem important and which may be of interest to the Iowa Academy of Science.

The analytical work on which the author has been engaged is now practically discontinued, not completed since the field seems almost without limit, and at present the results are being put in form for publication. During the course of the work there have been accumulated about four hundred analyses of the waters of wells of importance. These wells are fairly distributed throughout the state, and there are representatives in almost every county in the state. A total of about one thousand analysis and nearly as many descriptions of wells have been at hand to give good opportunity for generalizations on the subject under discussion. It is proposed in this communication to confine attention to three topics, the availability of ground water in this state, the present and probable future development of this resource, and the softening of hard water for industrial uses.

Certain physical features of the surface of the state of Iowa which contribute to decrease the importance of its surface waters as compared with other states are almost too obvious to require statement.

This is a state of comparatively level surface; that is, the differences of elevations above sea-level are small. Taken in detail its surface is gently undulating. There are no mountains, and scarcely anything worthy of the name hills. Ninety-five per cent of the surface is tillable and nearly the whole of it is under cultivation. There is thus very little wild land or forest area as compared with eastern states, to serve as collecting ground for lakes and rivers of good water. The soil is very deep and generally very fine and porous. Under it are the comparatively porous loess and the sand and gravel of the drift. The drift covers nearly the whole state and is very deep, over most of its surface. Though the state has an annual rainfall of nearly thirty-five inches, these conditions contribute to make the run-off small and the amount of water taken up by the ground very large. Owing to the deep drift covering the rock strata, the scarcity of outcrops and the generally unbroken surface of the land, perennial springs that might feed the streams during dry weather are comparatively rare. Without this source of supply, without forest areas to hold the water back, and with the porous soil to take up nearly the whole of the rainfall of the drier months it follows that many of the small interior rivers of the state contract to insignificance during the dry periods, usually of the summer and early fall. At all times and specially during the dry seasons their waters are subject to pollution by the surface drainage, sewerage of towns and commercial concerns along their courses. Owing to the large percentage of plowed land, the fine soil and clays, their waters are very turbid most of the year. In short, such streams as we who cast the fly find in Michigan and Colorado, with their strong currents of pure, clear water, derived from springs and forest covered sand layers, or from melting snow above the habitations of men, are unknown in Iowa. According to present sanitary standards there is no river in Iowa or on its border whose natural waters may be used the year through as the source of municipal supplies. The situation is likely to become worse rather than better as the population becomes more dense and the industrial interests expand and multiply. Unless some practicable plan of filtration adapted to the smaller places is devised it seems probable that rivers as the source of such supplies will continue to be of secondary importance.

Iowa is a state having few lakes of consequence. The only ones of importance form a group near the northern border of the state and well to the west. They are far removed from centers of population, they are fed by small streams, are shallow and they cannot be considered suitable the year around for town supplies. The same physical features that cause insufficient and poor river water also make large reservoirs or artificial lakes of good water practically unobtainable.

It is an interesting and important fact that the most of the conditions that contribute to make the rivers of smaller importance are the ones that increase the ground water resources and its easy availability. The level surface, the porous soil and drift, the large percentage of cultivated land increase the percentage of water absorbed. The deep soil and subsoil, the sand and gravel of the drift afford it storage. This filtered and stored water is in most regions easily reached by the bored well or the sand point. In very many areas the sand and gravel layers lie in basins or troughs and in such regions flowing wells are secured. In some regions such water-bearing layers are struck high in the drift, but a very large number of wells go to the rock and derive their water from gravel layers just above it.

The level nature of the land may also account for the fact that for the most part Iowa rivers and streams have low velocities of flow and meander through wide level valleys, instead of flowing with high velocity between ranges of hills as in more rugged countries. In such valley-plains of rivers, water supplies can be secured from the so-called "under-flow." In the southwestern part of the state where there are many such streams this source seems to be the best and the most generally resorted to for town water systems. Good examples are Atlantic, Red Oak, Elliott and Griswold on the Nishabotany. Such waters have the advantage that they contain about the same amount or very little more mineral matter than the waters of the rivers themselves.

There remains to be mentioned the unparalleled source of well water in the northeastern part of the state,—the sand-stone layers of the Cambrian and Ordovinchian systems, known as the St. Peter, New Richmond, Jordan and Dresbach. This magnificent source is too well known to require further mention. It may be of interest to note, however, that in at fewest five of the most favorably located counties this source is untouched, and in several others one finds only one or two wells to each county.

Such are the well water resources of the state. To what extent are they being used or to what extent are the people dependent upon them? That well waters have up to this time held the most important place appears strikingly from a study of the municipal water systems of the state. The following figures are from the Underwriters' Hand-book of Iowa, in which are given all the towns of the state with their populations and their means of fire protection. The populations are taken from the last census, though the edition of the book is for 1907.

In going over the list the following facts appear. There are 324 cities and towns having water systems, including stand-pipes, street mains and fire taps. Towns having systems for fire protection only are not included. Of this number six have as their sources of supply lakes, or natural or artificial ponds; twenty-four have water from rivers, and 294 get their water from wells. It appears further that the urban population in towns having water systems are supplied as follows:

From lakes and ponds	21,000
From rivers	341,000
From wells	534,000

It follows that well water supplies about 60 per cent of the dwellers in such towns But, this is only a part of the truth. The inhabitants of such towns are a comparatively small minority as compared with the whole population of the state. There are many large towns without water systems. The people of these towns and the whole rural population are dependent upon wells of one sort or another. Taking this fact into account it follows that about 84 per cent of the whole population are dependent upon ground water.

There is much reason to expect a greater proportionate development in the use of ground water, and water from deeper sources. Though there are many towns of 150 to 300 inhabitants that have water systems, there are also many of 500 to 2,000 people that are yet without such systems. They will be forced to provide such supplies in the near future. The indications are that many towns have installed water systems more or less temporary and to meet the then existing needs, whether this temporary character was intentional or not. There is observable a very general tendency to extend well systems and to put down deeper wells as the towns have grown. It is interesting also to note the tendency to provide unfailing water supplies on the farms. Iowa is getting to be a state of very large live stock interests. Stock must have water, and something better than the shallow well, located very likely in some draw, only a few feet deep and provided it may be with only a hand pump, has become a necessity. The result is that farm wells 100 to 500 and even 1,000 feet in depth are becoming very numerous, and it is very probable that with the increasing need of plenty of good water, and also the increasing wealth of farmers in Iowa such farm wells will become very general.

In the former paper referred to, mention was made of the corrosion of well casings by hard waters. Several instances are on record where casings or parts of them have been taken out of the wells and found full of holes due to pitting. There is evidence that this is very general in wells having hard waters, and though no very accurate data have been collected the probability is that ordinary iron tubing in wells having quite hard water will be eaten through in from five to ten years. The following is an interesting example in a well in the southern part of the state and in a particular locality where the upper water is very highly mineralized. The well was drilled in 1904 to a depth of 2,054 feet. The following are four analyses of its water made at intervals of about one year.

Date of Analysis.	Total Solids.
Sept. 18, 1905	1,228
Sept. 9, 1906	1,637
Nov. 26, 1907	1,930
Sept. 9, 1908	2,594

The content of mineral matter has steadily increased during the four years, and it seems very likely that this is due to the gradual deterioration of the casing due to corrosion.

The want of efficiency and durability in the casings is one of the chief weak points in the deep well as a source of water supply. Not only do casings rust through, but in many instances they do not reach sufficient depths to shut out hard water and to prevent caving of shale. The town of Grinnell has lost one well and the capacity of another in quality and quantity has been greatly diminished by the caving of shale at the depth of about 1,700 feet or just above the St. Peter. At the present time well number (4) is being drilled and has reached a depth of 1,850 feet. The plans and contract regarding casing are so unusual, and are likely to be of such importance that a mention of them seems desirable.

As is well known cast iron far excels wrought iron in its resistance to the corrosive action of air and water. Of course, the mild steel which has so largely replaced wrought tubing on account of its cheapness is still far inferior to wrought iron in durability. Having had experience with both soft steel and wrought iron tubing the Grinnell authorities contracted for a casing of cast iron in well number (4) to reach to a depth of 1,700 feet. If this experiment succeeds it ought to be of much interest from both the practical and scientific standpoints. There are few if any deep wells near the center of the state from which the waters above the great sandstone layers are entirely excluded. No one now certainly knows what these sandstones are capable of yielding in this region in either the quality or the quantity of water. In the Grinnell wells as they have hitherto been cased, very considerable quantities of hard water have been received from the limestone layers below the casings at depths from 1,200 to 1,600 feet. If the water supply of the new well should prove abundant and should have a mineral content anywhere near as low as the water from the same strata fifty miles to the northeast, it ought to encourage more deep wells in this region, and even the extension of the region of artesian wells farther to the south and west. In any event the successful putting down of this casing will demonstrate the practicability of cast iron for this purpose, and the opportunity of thus very greatly increasing the durability of the casing and the life of the deep well.

Iowa waters from whatever source are notably harder than those from corresponding sources in the states farther east. The waters of Lake Michigan and of the great lakes generally contain about 130 parts of solid matter per million; lakes and rivers farther to the east contain smaller amounts, even to less than half as much. On the other hand the softest of Iowa river, lake and well waters contain about twice that amount; that is, about 260 parts per million. There are few well waters of this degree of freedom from mineral matter. Excepting a few wells the great majority vary from 350 to 10,000 parts. On Iowa standards a town with a supply of water containing 500 parts of solids per million may consider itself fortunate in this respect; 700 parts may be considered fair, and 1,000 parts or even more, tolerable. For boilers and most industrial purposes none of these could be considered very good.

One railroad in the state has classified its waters according to standards as follows: less than 134 parts, of incrusting solids, very good; 200 parts, good; 300 parts, fair; 450 parts, poor; 600 parts, bad; over 700 parts, very bad. According to this standard and its own analyses of waters along its lines no water can be considered very good; only eight of its waters are good; thirty-seven are fair, and eighty-eight are poor to very bad. If the 123 waters of this road may be taken as representative and the standard quoted as valid, then about two-thirds of the Iowa waters are poor to very bad for boiler use. The case is really worse. Railroads care little about the sanitary condition of their boiler waters, and they take them from rivers, ponds and slough wells by preference because they are softer than the waters from deeper wells such as supply cities. Of city supplies probably far more than two-thirds are really poor to very bad for boilers.

That hard waters form boiler scale and are very likely to be corrosive are facts too well known by this body to require discussion; also, that scale decreases the efficiency of the boiler, and corrosion means early and frequent repair and short life of the boiler.

Many means have been devised with the object of avoiding these difficulties. From the standpoint of the chemist there is only one right way, if the water is to be used at all and is not bad beyond possibilities of treatment. Since this method has now been introduced on a very large scale in this state by one of the largest corporations and has proved very successful, at any rate a brief statement for record seems desirable. But first as to palliatives and quack remedies.

If one wishes to avoid the difficulties attending the use of a hard water for boilers or other industrial purpose, the most obvious thing to do is to soften it, if this is practicable. There is nothing new in the idea of softening water; the chemistry of it has been known for a long time, but there are new developments in methods and the scale on which it may be carried on, at any rate in this state, where on account of the hardness of the waters it should be a matter of very great industrial importance. In order to make more clear the scientific character and efficiency of the method I have mentioned it may be well to describe briefly two palliative methods as carried out on a small scale.

One method is by use of the pre-heater, the source of heat being usually exhaust steam. It is a matter of economy to feed the boiler with heated water, and the heating causes the precipitation and settling out of a considerable portion of the calcium carbonate. Sometimes a boiler compound or an alkali is added to the heater, thus removing a portion of the permanent hardness. The method is good so far as it goes, but the apparatus is usually too small to allow proper settling, it is troublesome to manage and its efficiency is farther restricted by the want of knowledge and care of the individual engineer.

Perhaps the most generally used and the worst method is that of using alkalies and so-called "boiler compounds" for the precipitation of the solid matter in the boiler. This makes the sludge where it will do the most harm. It may cause foaming, it necessitates frequent cleaning, it may settle in a compact mass when the boiler is out of use and cause overheating of the covered plates and even explosion when the fires are again started. As a rule in practice the nature and amount of the boiler compound bear little relation to the work to be done, the compound of unknown composition being added from time to time without much regard to the mineral content of the water or the amount of water used. The treatment is likely to be only partial, or the compound is likely to accumulate and cause trouble.

The number of boiler compounds on the market is very large and for them their venders claim almost miraculous properties, and they sell them at exorbitant prices. A few days ago there came into my hands a boiler compound used in a Grinnell power plant. So far as could be discovered it contained only sodium hydroxide, about 18 per cent, and a very little coloring matter that may have been due to the action of the strong alkali upon the barrel. It was bought by the barrel at eight cents a pound, or about $42.00 a barrel. It was actually worth, barrel and freight included, about $5.00. The man who bought this compound is one of unusual intelligence and business ability. In fact, the appeal of the boiler compound to the trade may be likened in many respects to that of the patent medicine, and mystery seems to be the controlling factor. Now, as a matter of fact there are only a few practically useful chemicals for softening water, and they are all perfectly well known as is also their action. There is no necessarily efficient nostrum applicable in all cases. Any peculiar, secret and patented combination ought to be treated as a fraud, and the engineer who applies to a chemist for advice should be plainly told this fact.

The chief substances in water that make boiler scale are calcium and magnesium in association usually with carbonic and sulfuric acid ions. The scale consists mainly of calcium and magnesium carbonates, hydroxides and calcium sulfate. The chief agents of corrosion are free carbonic acid, and other acids that may be set free by the hydrolysis of salts at the high temperature of the water. The problem is, therefore, to remove calcium and magnesium (secondarily aluminium and iron), and carbonic acid ions, to leave the water neutral or slightly alkaline, with the introduction of the minimum of soluble material.

First of all one must have an accurate mineral analysis of the water to be softened. The volume of the water must be measured and the chemicals must be calculated to meet the given case and the amount used weighed. Though there is no logical procedure applicable to all waters, effectiveness and cheapness both considered, it is generally better to use only lime if the calcium and magnesium ions do not exceed in equivalence the carbonic acid ion, HCO^3; otherwise a mixture of lime and soda ash serves the purpose best. The absolute amounts depend, of course, upon the quantities of substances to be removed, and their relative amounts must be varied according to the infinitely varying proportions of the ions, Ca, Mg, HCO^3 and SO_4. Every water must have its own proportions precisely adapted to its mineral content. The chief reactions in such water softening are represented by the following equations:

1. $Ca(HCO_3)_2 + Ca(OH)_2 = 2CaCO_3 + 2H_2O$.
2. $Mg(HCO_3)_2 + 2Ca(OH)_2 = 2CaCO_3 + Mg(OH)_2 + H_2O$.
3. $MgSO_4 + Ca(OH)_2 = Mg(OH)_2 + CaSO_4$.
4. $CaSO_4 + Na_2CO_3 = CaCO_3 + CaSO_4$.

Equations (1) and (2) show the removal of calcium and magnesium carbonates, or "temporary hardness." When the water contains sulfates of these elements, that is, is "permanently hard," sodium carbonate is also used, and removes calcium sulfate already present or formed as in (3) by the reaction expressed in (4).

The chemical scheme that I have outlined is the one that is being used by the railroads of Iowa so far as they have taken up the enterprise. The present situation is indicated by the following points from the correspondence with the chief chemists, or engineers of tests as they are in some cases called. Mr. M. H. Wickhorst of the Burlington road writes that they have installed three large plants which are giving very satisfactory results. Mr. Geo. D. Prentiss of the C., M. & St. P. states that his road has attained excellent results at Sioux City and in another plant across the river in South Dakota. Mr. F. O. Bunnell states that the Rock Island could scarcely maintain its present schedule in some regions without the softening plants, and that their system of softening would probably soon be extended to Iowa.

To the Chicago & North-western railroad, however, is due the credit of the widest application of water softening on a large scale. The information at hand comes from Mr. Geo. M. Davidson, engineer of tests for many years, through correspondence and a paper on the North-western softening system, published in the Western Railroad Club.

This road has in successful operation forty-one softening plants, of which twenty-two are in Iowa. With three exceptions these plants have a capacity of 240,000 gallons a day. The chemical process has already been essentially described. Only a few of the prominent mechanical features and the results can be given.

The apparatus is comparatively simple and is constructed in the shops belonging to the road. The essential vessels, excluding the storage tanks for the hard and for the softened water are, a small tank to hold the mixture of milk of lime and sodium carbonate, the mixing tank provided with stirring blades, and two settling tanks. The hard water receives the softening solution just before it reaches the measuring apparatus, which consists of a two-compartment tilting box, each compartment holding 100 gallons. The tilting vessel operates two pumps whose cylinders supply the softening solution and the length of the stroke can be regulated to supply the desired volume. The weight of water in the tilting vessel is also the source of power to operate the stirring blades and they are reversed with every change of position. From the mixing vessel the water goes to the settling tanks of which there are two, each having a capacity of 77,000 gallons. From them the clear water is pumped to the storage tank for use.

The effectiveness of the process may be illustrated by the results attained by three plants, at Council Bluffs, Denison and West Side. The average of the incrusting solids of the untreated waters is 644 parts per million, and of the treated waters seventy-four parts. About four grains per gallon or seventy parts per million of incrusting solids marks the usual efficiency without much regard to the character of the water originally. This amount is regarded as practically harmless.

The results of the use of this softened water in railroad engines have been very gratifying. The first effect in boilers that have used hard waters is to cause leakage owing to the loosening of old scale. If the tubes are then re-rolled there is very little farther trouble, and the general results is that boiler repair and time lost by engines in the repair shop are reduced to a small fraction of what they were when untreated water was used.

The cost of treatment varies greatly with the degree of hardness of the water. Fair boiler waters cost about one cent per 1.000 gallons. From this minimum the cost increases to ten cents, with the average about three cents per 1,000 gallons.

All waters cannot be made good boiler waters by softening. Very hard waters are likely to contain already some sodium sulfate. To remove calcium sulfate by the method described means necessarily an increase of sodium sulfate. If the total quantity present exceeds about 600 parts per million, the result is foaming in the boiler.

Iowa waters are hard and trouble with them in boilers and in other industrial uses is well-nigh universal. The trouble will not disappear of itself, but will become more acute as the industries of the state increase. I deem it worth while to call the attention of men of science to this most scientific remedy which has been proved wholly practicable on a large scale. It ought to be as practicable for a large stationary power plant or a manufacturing concern as for a railroad. In every town of considerable size there are numerous power plants, often laundries, tanneries and the like, and it would seem reasonable for them to unite in the erection of a softening plant for their common use if the method of solving their difficulties regarding water were made clear.

THE ANALYSIS OF SMALTITE WITH SPECIAL REFERENCE TO THE ESTIMATION OF ARSENIC AND COBALT.

BY NICHOLAS KNIGHT.

A gram of the substance is weighed into a porcelain crucible of 150 c. c. capacity, 50 c. c. of dilute nitric acid are added, and evaporated to dryness on the water bath. The nitric acid is removed with sulphuric acid. This treatment changes the lead sulphide that may be present to lead sulphate, which with the silica is removed by filtration.

The filtrate is diluted to a volume of 200 c. c. and heated to 60°-70°, while a stream of hydrogen sulphide is run into the liquid for three to six hours. This precipitates arsenic, bismuth and copper, all the other substances remaining in solution. After filtering and washing the precipitate in cold water, it is treated with warm potassium sulphide. This dissolves arsenic sulphides, while bismuth and copper sulphides remain unchanged.

The solution of arsenic is evaporated to dryness on the water bath, and if sulphides of arsenic and copper separate from the solution as may happen, these are filtered, and added to the other portion.

The arsenical residue is transferred to a 150 c. c. crucible and five to seven grams of solid caustic potash are added. Then a stream of chlorine is run into the crucible for twenty or thirty minutes, or until the contents of the crucible bleach litmus paper.

With the crucible covered by a watch glass about 50 c. c. of dilute hydrochloric acid are added, and then evaporated until crystals appear. The operation is then repeated, using 50 c. c. of concentrated hydrochloric acid.

By the use of hot water, the contents of the crucible are transferred to a beaker glass and filtered to remove the sulphur and silica. The filtrate containing the arsenic is diluted quite largely with water and kept at a temperature of 60°-70°, while a stream of hydrogen sulphide is introduced for three to six hours. The arsenic sulphide may be collected in a Gooch crucible or on a tared filter.

The reactions:

$CoAs_2 + 6HNO_3 = Co(NO_3)_2 + 2H_3AsO_4 + 4NO.$

$2H_3AsO_4 + 5H_2S = As_2S_5 + 8H_2O.$

$As_2S_5 + 3K_2S = 2K_3AsS_4.$

$K_3AsS_4 + 40KOH + 32Cl = 4K_2SO_4 + 32KCl + 20H_2O + K_3AsO_4.$

Pot arsenate.

The excess of KOH and Cl becomes $2KOH + 2Cl = KClO + KCl + H_2O$ and $3KClO = KClO_3 + 2KCl.$

Adding dilute HCl,

$2HCl + KClO = KCl + 2Cl + H_2O$, the hypochlorite and also the K_2CO_3 are decomposed. The K_2CO_3 is formed by the action of the CO_2 of the atmosphere upon the caustic potash.

It is also necessary to add Conc., HCl to decompose the $KClO_3$ as follows:

$KClO_3 + 6HCl = KCl + 6Cl + 3H_2O$.

$K_3AsO4 + 3HCl = H_3AsO_4 + 3KCl$.

$2H_3AsO_4 + 5H_2S = As_2S_5 + 8H_2O$.

After the first filtration of the arsenic, the iron is next determined, followed by the estimation of nickel and cobalt as follows: The filtrate from the iron is evaporated to a smaller volume, and both nickel and cobalt are precipitated as hydrates with caustic potash. The hydrates are filtered off, removed with a feather to an evoporating dish, and hydrocyanic acid is added until a reddish tint, not very pronounced, is assumed; then a solution of caustic potash, drop by drop, until all is dissolved save a small flocculent precipitate of cobalt paracyanide. This is filtered through the same paper from which the precipitates were removed.

The filtrate is concentrated to a small volume, and mercuric oxide, suspended in water is added until the liquid remains a red color. This is Liebig's method of precipitating the nickel. It is left about an hour on the water bath, when the nickel is removed by filtration.

The Cobalt. The filtrate from which the nickel was removed is evaporated to dryness in a platinum dish. The cobalt paracyanide is now united to this main portion. About 30 c. c. dilute sulphuric acid are added, and after half an hour the same quantity of strong acid. It is evaporated to as small a bulk as possible on the water bath, and cautiously heated with the free flame to remove all sulphuric acid. The residue is treated with a little water and the mercury salt that it usually contains is removed by filtering. The filtrate is once more evaporated to dryness, and again filtered to remove the last traces of mercury.

The filtrate on the water bath is precipitated hot with a solution of caustic potash. The well washed precipitate is finally reduced to metallic cobalt with a stream of hydrogen.

The reactions:

$Co(NO_3)_2 + 2KOH = Co(OH)_2 + 2KNO_3$

$Co(OH)_2 + 2HCN = Co(CN)_2 + 2H_2O$.

KOH and HCN are added until the double salt, potassium Cobalto Cyanide, $Co(CN)_2$, 4KCN is formed. Expressing this double salt in another way we have $K_4\ Co''(CN)_6$.

$2K_4\ CO(CN)_6 + O + H_2O = 2K_3Co'''(CN)_6 + 2KOH$.

There is a change of valence from two to three.

Adding dilute sulphuric acid there results:

$K_3Co(CN)_6 + 3H_2So_4 = 3HKSO_4 + H_3Co(CN)_6$.

The concentrated sulphuric acid reacts as follows:

$2H_3Co(CN)_6 + 19H_2SO_4 = 2CoSO_4 + 12CO + 12N + 17SO_2 + 22H_2O$.

Heating to dryness changes the $HKSO_4'$ — $2HKSO_4 = K_2S_2O_7 + H_2O$.

$CoSO_4 + 2KOH = Co(OH)_2 + K_2SO_4$

$Co(OH)_2 + 2H = Co + 2H_2O$.

THE FRUIT OF VIBURNUM NUDUM.

BY ROBERT H. LOTT AND NICHOLAS KNIGHT.

The fruit of Viburnum Nudum was gathered in the swampy portions of the territory around Sylvan Beach, N. Y., on the eastern shore of Oneida Lake, August 27th to September 5, 1907. The territory was formerly the lake bottom, at the time when the water was discharged into the Mohawk river. An elevation of the land took place, the lake was projected farther north, and the water now reaches Lake Ontario through the Oneida and Oswego rivers. The soil of the Sylvan Beach territory is almost a pure sand, unadapted to agricultural purposes.

This species of Viburnum grows on shrubs four to seven feet in height. It is common in swampy regions from the New England states to Florida.

The portion gathered August 27th was comparatively green, while on the 4th and 5th of September it had become quite ripe. It was then a beautiful cardinal red, very abundant in the neighborhood of Sylvan Beach, and the most gorgeous object in the early autumn landscape.

The dried fruit of the species consists of berries that resemble commercial currants. They differ in that their color is bluish black instead of brownish black, and they are more elongated. The odor of the berries is also similar to that of currants.

The taste of the berry passes quickly through different degrees of sweetness to that of a decided bitterness. The bitter taste is very similar to that of a wild cherry, or to the bark of a peach tree, although not quite so strong. The fruit when burned gives off three distinct odors; first, a sweet odor like that of taffy made from sorghum molasses; secondly, an odor somewhat resembling coffee; and lastly, the odor of burning damp straw or leaves, which is very penetrating. The fruits are very easily crushed in an agate mortar. There were 270 grams available for the analysis. The average weight of each was 0.05 gram.

THE SUGARS.

About 100 grams of the fruit were taken for the sugar extraction. They were placed in a 500 c.c. flask, fitted with an inverted condenser, and treated with successive portions of alcohol for about thirty-five days. The alcoholic extraction was removed each day, and a fresh portion applied. The alcohol was distilled off, and two substances remained behind; one a dark, thick syrup; the other a resinous, gummy substance possessing a bluish clay color. The alcoholic extraction gave an acid reaction to litmus paper. The color and odor of the first extraction bore a strong resemblance to new cider. In a short time the odor resembled old cider, and a test for acetic acid showed that fermentation was taking place.

A test with Fehling's solution at the end of thirty-five days showed that the sugars were almost extracted, and distilled water was substituted for alcohol. The berries under the alcohol treatment remained hard, but on the addition of water became soft and mushy. The alcoholic extraction at the end of thirty-five days was almost colorless, while the water extraction was very black, resembling coffee that had been boiled. Ten days more were required to remove all coloration and the remainder of the sugars by the water treatment.

The percentage of the sugars was determined by Fehling's solution of such a strength that 10 c.c. corresponded to 0.05 gram sugar. The determination was made by taking 1 c.c. of the sugar extraction and diluting with 50 c.c. of distilled water in a small beaker. This was heated to boiling and titrated with Fehling's solution. To ascertain when the end point was reached, a small portion of the solution was filtered from time to time, always pouring the filtrate back, until the sugars had no more reducing power. The filtrate was of a marked straw color until the reduction was complete, at which time it became a light blue. The change in color could be brought about in either direction by three drops of the sugar solution or the same of Fehling's solution, and so it seemed a satisfactory test. There were found to be 42.85 grams of sugar corresponding to 42.85 per cent. The loss by fermentation was not ascertained.

The two different sugar extractions were evaporated to dryness, and the odor was that of scorched sorghum. The residue was a black thick jelly-like substance and had the bitter taste of the original berry.

A portion of this residue was purified by heating for several hours on the water bath with purified bone black. The solution was quite light in color, and was evaporated to dryness for treatment with phenylhydrazine.

With portions of 0.01 gram sugar, 0.04 gram phenylhydrazine, and 0.03 gram sodium acetate, the test pointed to fructose. Another test with cobalt nitrate indicated dextrose, so it is quite likely both are present. The osazone crystals were purified by crystallizing with alcohol, and attempts were made to obtain the melting point, but the efforts were unsatisfactory.

The residue of the fruits after the sugar extraction was dried and weighed. The loss of weight was 53 per cent. The berries were black in color, shriveled and hard.

As a larger quantity of residue was needed for oil extraction, it seemed likely that the sugars might be removed more rapidly by using a litre flask and larger quantities and changing the solvent twice daily. In two weeks all the sugar in 125 grams of fruit was extracted. This portion was dried and weighed, showing a loss of 48 per cent as compared with 53 per cent the first time.

THE ASH.

Four different portions of the berries of about two grams each were ashed in a platinum evaporating dish of 100 c.c. capacity. From the first portion silica, iron, aluminum, calcium and magnesium were determined; from the second portion, the sodium and potassium by a modification of the J. Lawrence Smith method; from the third portion, the sulphates,, and lastly, the phosphates. The analysis showed more sodium than potassium, and the flame test both from the original berry and the sugar syrup pointed in the same direction. The results of the analysis were as follows:

FIRST PORTION.

SiO_2	2.11 per cent of the ash
Al_2O_3	3.88 per cent of the ash
Fe_2O_3	3.88 per cent of the ash
CaO	7.60 per cent of the ash
MgO	1.87 per cent of the ash
Weight of berries taken	2.015 grams
Weight of the ash	.09 grams

SECOND PORTION.

K_2O	12.87 per cent of ash
Na_2O	16.79 per cent of ash
Weight of berries	2.0403
Weight of ash	0.0933

THIRD PORTION.

SO_3	27.13 per cent of ash
Weight of berries	2.0533
Weight of ash	0.0921

FOURTH PORTION.

The phosphate was determined by dissolving the ash in nitric acid, filtering and treating the filtrate with a solution of ammonium molybdate.

P_2O_5	12.89 per cent of the ash
Weight of berries	2.0523 grams
Weight of ash	0.0734 grams

The total is 89.09 per cent of the ash; the remainder is organic matter that escaped combustion, and carbon dioxide.

A portion of the pulp of the berries after the sugar and oil extractions was thoroughly dried, and 2.6083 grams ashed. The ash weighed 0.0483 grams, about half the weight of the ash of the original fruit, and a much larger bulk of fruit was required to weigh two grams than of the original fruits. The pulp now had only two characteristic odors, that of coffee, and of damp burning leaves. The odor of taffy seemed to have disappeared.

THE OILS.

The dried berries from the sugar extraction weighing 112 grams, were finely ground in a small coffee mill, and used for the oil extraction. The powder was placed in a 500 c. c. flask which was tightly fitted with an inverted condenser, and treated with ether. Two weeks were required to extract all the oil. The ether was removed from the oil by distillation. The oil at first was of a beautiful green color, due no doubt to chlorophyll. The attempt was made to remove the chlorophyll by filtering through bone black, with ether, in the cold, but no effect whatever could be detected. The oil was then heated for twelve hours with ether and bone black, using an inverted condenser, and then filtered The oil now came out a beautiful amber color, the specific gravity of which was 0.9353. It was not possible to solidify it in a freezing mixture. The boiling point is about 82°. It has a characteristic odor which somewhat resembles that of olive oil. Four saponifications were made by Koetstorfer's method which resulted as follows:

	Amount Taken	Time Heated	Saponificat'n Equivalent
1	0.857	2	612
2	0.858	4	343
3	2.302	12	291
4	3.1605	16	303

The results indicate that the oil is difficult to saponify, and that complete saponification takes place only after continued heating. The figures show that the oil is one of the oleins in the same group as castor oil, almond oil and olive oil. The conclusion accords well with the physical characteristics.

The products of the third saponification were separated. The soapy solution after saponification was diluted with distilled water, and a quantity of ether was added which dissolved the unsaponifiable portion. This was separated from the liquid, evaporated to constant weight and found to be 0.0483 grams. This residue was dissolved in hot alcohol and filtered, and left to evaporate spontaneously. A few minute crystals separated out which were supposed to be chloresterol.

After separating the ethereal layer, the remaining liquid was acidified with sulphuric acid and slightly heated, whereupon the fatty acids liberated by saponification collected upon the top of the liquid. These were separated and boiled with distilled water for several hours. They were afterwards separated from the water, dried on the water bath, and found to weigh 3.6033 grams more than the amount of oil at first taken. The increase of weight is due, doubtless, to the oxidation of the acids. Two distinct acids appeared, one very clear and odorless, which crystallized in a freezing mixture to fine needles, and melted at about 4°, the other was a yellow limpid liquid with an odor resembling lard. This last crystallized at a low temperature, but we did not succeed in finding the melting point. Judging from the descriptions given in the literature, the clear acid seems to be oleic, and the yellow one is linoleic. Both reacted acid to litmus paper.

An attempt was made to obtain the weight of the soluble fatty acids. The acidified liquid was first separated from the insoluble fatty acids, and the distillate exactly neutralized by normal caustic soda, using phenolphthalein as an indicator. The washings from the insoluble acids were now added to the contents of the flask and again distilled to a small bulk. This distillate likewise was neutralized with normal caustic soda. The two distillates were evaporated to dryness to constant weight. The number of centimetres used in the neutralization was multiplied by 0.022, and the product subtracted from the constant weight. The result was unsatisfactory. Each fruit bears a single flat stone which undoubtedly contains the oils. We obtained in all 14.5667 grams of oil from 225 grams of the original fruit or 6.47 per cent.

THE PROTEINS.

Some of the berries were crushed and boiled in distilled water for a short time. A small amount of this solution was heated with nitric acid, giving a yellow color, which became an orange red when made alkaline. This showed the presence of albumen.

A portion of the fruit was heated with an excess of soda-lime in a dry test tube. The fumes reacted alkaline to litmus paper. A similar effect was produced by heating the berries alone at a high temperature.

The nitrogen was determined by the Kjeldahl method; 2.0933 grams of the berries gave 0.0112 gram of nitrogen, equivalent to 0.53 per cent.

A quantity of solution which resulted from boiling the berries in distilled water was tested to learn if the albumen contains sulphur. We treated a solution of lead acetate with caustic soda until the precipitate which first forms is redissolved. The fruit solution was now added to this and heated to boiling. A dark colored precipitate of lead sulphide formed which indicates the presence of sulphur.

THE ACIDS.

The acid tests were made from the sugar extraction. Tartaric and citric acids were found, with a small quantity of malic acid. Citric acid seemed to predominate.

SIGNIFICANCE OF THRUST-PLANES IN THE GREAT BASIN RANGES.

BY CHARELS R. KEYES.

For more than a generation no other hypothesis of the rearing of the mountain ranges of the Great Basin has been countenanced except that of simple normal faulting on a gigantic scale. This is the explanation offered by Gilbert*. It has its foundation in the observations made by this investigator in the Grand Canyon region of Arizona.

While faulting is widely known in the Great Basin country, it is one of the most surprising of facts that few fault-lines have ever been discovered at the foot of the Basin ranges. Whenever the greater lines of displacement are located it is almost invariably the case that they are not at the base of the mountain ridges, but at a distance of several miles out on the adjoining plain†. The mountains are in the main symmetrically developed. The longer ridges have usually a distinct bilateral symmetry. These facts are suggestive of some inattention to the time-factor of the major faulting. In the majority of cases in which critical evidence has been adduced the dates of the principal displacements are not nearly so recent as had been assumed. Instead of being quite late geologically the period appears to be quite early. Probably most of the more profound faulting took place in Jurassic times. While without question fault movements have been continuous since the beginning of Mesozoic times, and are even now in progress as Spurr‡ has lately noted, the main displacements are ancient.

Recent investigations have had especially in mind the determination of the dates and of the kinds of the various crustal adjustments in the Great Basin country. On the whole, the later movements of the great rock-masses appear to be largely the result of compressive rather than of normal strains. The infolding of old lava-sheets in deposits of Eocene, Miocene, and Pliocene ages, in the Death Valley district of eastern California, for instance, is particularly suggestive. Similar marked flexing of Tertiary strata is now known in many other places in the same region.

The compressive character of the acquired geologic structures is especially well indicated by certain enormous thrust-planes which have been recently noted. Although the exact dates of some of these phenomena are not as yet clearly fixed the positions which some of them occupy seems to point to the fact that the accompanying movements may have had much to do with the rearing of the mountains themselves. The importance of the recognition of the presence of thrust-planes in many of the desert ranges lies in the inference that

*Geog. and Geol. Expl. and Surv. W. 100 Merid., Prog. Rept., p. 48, 1874.
†Bull. Geol. Soc. America, Vol. XIX, p. 63, 1908.
‡Bull. Geol. Soc. America, Vol. XII, p. 217, 1901.

we may have to ascribe to the mountains of the region generally, even when normal faulting is in evidence, an initiatory genesis through reversed faulting.

Second only in importance to this important observation is that of the possible radical difference in expression of compressive strains in great rock-sections composed entirely of brittle masses and these of masses made up of alternating beds of weak and resistant rocks, especially when the former greatly predominates. Through great compression the tectonics of the western country would thus be quite distinctive from that of the eastern, or Appalachian, field. In the last mentioned region the rock-masses include numerous thick zones of yielding shales. Under compression from the sides such masses would easily flow, as it were, enabling the more rigid and brittle layers to become severely flexed into a series of close folds without loss of their continuity. In the Great Basin region there are practically no shale beds except the late clays. In the entire Paleozoic section, which is upwards of 15,000 feet in thickness, there are very few layers that would yield to flexing. Under these conditions folding would in any case be very slight. With brittle rock-masses only breakage and shearing would be possible. As shown by Irving* for the Wisconsin region, great movement in such rocks is likely to take place only through a narrow belt. Thousands of feet of movement may be expressed within a space of a few hundred feet with no other break within a distance of many miles on either side.

In the desert region of the West the conditions are not so favorable as they might be for obtaining critical evidences bearing upon this point. The foots of the mountains are almost invariably covered by ever-shifting loose materials. So far as known the desired data have never been especially sought. The only published suggestion that is now recalled of this mode of mountain origin is in the cases of the Sierra de los Caballos, the Sierra Oscura, and the Sierra San Andreas, in south-central New Mexico†.

If the thrust be the true explanation of some of the Great Basin ranges then the mountains of this region are not to be put in a class so very different from that to which the Appalachians and the Juras belong. The specific difference is only in the character of the rocks composing the mountains. This, however, may give rise to very diverse geologic structures.

It is also now known that there have been great tortional movements in many parts of the American arid region, by which long ranges have undergone considerable lateral displacement. Abundant evidences of this phenomenon are to be seen in the Sandia and Manzano ranges, and in the Caballos, Cochillo and Fra Cristobal mountains‡. This phase of the subject is of very great interest and is worthy of careful and extended inquiry.

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*U. S. Geol. Surv., 7th Ann. Rept., p. 390, 1888.
†Journal of Geology, Vol. XIII, p. 64, 1905.
‡Proc. Iowa Acad. Sci., Vol. XII, p. 163, 1905.

OROTAXIAL GEOLOGIC CORRELATION AND DIASTROPHISM.

BY CHARLES R. KEYES.

Exact stratigraphic correlation is today bothering the geologist more than any other subject relating to earth knowledge. This phase of geology has, indeed, been a constant source of embarrassment ever since the science's birth more than a century and a half ago. A hundred years ago William Smith, an English engineer, discovered the use of organic remains in the determination of the relative ages of rocks; and since his time fossils have been very generally depended upon in unravelling the geologic history of the various parts of the globe.

During the last quarter of the last century stratigraphy began to demand quantitative, instead of merely qualitative, results. Other stratal criteria of a critical character were found to be, in the field, of even greater practical value than the fossils could ever hope for. At the present time most of the geological surveys have adopted a lithologic standard for the geologic unit in mapping; and the fossils come to have only a secondary importance, or are ignored altogether. Even this scheme has not proved to be so satisfactory as was anticipated. It is now quite manifest that we shall have to seek more fundamental criteria in the interests of exact geologic correlation. We shall have to look more carefully into the factors which control sedimentation, which modify it, and which delimit the geologic terranes.

Every classification of natural objects is very simple and very perfect so long as we make no comparisons with other methods and do not adopt any other criteria. For example, we may classify plants by means of their flowers; or by their leaves. We may arrange systematically the mammals according to their teeth. So, also, we may construct an elaborate stratigraphic scheme in accordance with the contained fossils and have, to all appearances, not only a complete but a seemingly flawless plan. This for the last hundred years the paleontologist has tried to impress upon us. It is, however, a classification of organic remains and not necessarily of geologic formations.

When we make comparisons with other standards, which seem equally critical, the shortcomings of the paleontologic method become alarmingly glaring. When closely examined the paleontologic scheme of geologic classification is found to be not a classification of terranes at all, nor a logical arrangement of historic events, but merely a rather imperfect grouping of faunas. The question arises whether in stratigraphy we should not be better off today if we were to ignore the fossils altogether, or recognize them only in the most general way.

At the meetings last winter in Baltimore of the American Association for the Advancement of Science, and of the Geological Society of America, there was a notable symposium on geologic correlation occupying the time for several days. This fact alone is indicative of the great interest which is being taken in the subject at the present time. The most suggestive paper of all, perhaps, was the one presented by Professor Chamberlain, of the Chicago University. In it was urged the use of diastrophism as an ultimate basis of geologic correlation. This is essentially the utilization of the expressions of the local changes in elevation or depression of the surface of the globe, particularly along the sea-coast, due to mountain-making and epeirogenic movements.

Now, it may be of no little interest at this time to recall the fact that eleven years ago there was read before this Academy a paper* on this very subject. It was entitled "Some Physical Aspects of General Geologic Correlation." This paper was a more mature consideration of an article published in the *American Geologist* three years before†, and called "Orotaxis: A Method of Geologic Correlation." Since that date I have referred on several occasions specifically to the subject‡, particularly in treating§ of the "Orotaxial Significance of Certain Unconformities."

As originally stated** the definition of orotaxis, or stratigraphic correlation upon the basis of diastatic, or diastrophic, movements is essentially as follows: "The immediate causes for the changes between the relations of the land and sea areas are to be sought in orogenic and epeirogenic movements. As the two kinds of movements cannot be readily separated practically, and as it is of small advantage to separate them theoretically, the results produced may be all regarded as arising from the one cause—that is, from mountain-making forces. The greatest and most abrupt modification in sedimentation, and consequently in lithologic, faunal, and, in fact, all characters, are those connected directly with diastatic change, producing depression of some land areas below sea-level, and the uprising of other districts above the level at which they once stood, to form those great features of the earth's surface called mountains. Geologic chronology, therefore, is believed to find a true and rational basis in those changes which primarily govern sedimentation and which are intimately connected with the genesis of mountain systems. It is proposed, therefore, to emphasize this factor as fundamental in the marking out of the leading subdivisions of geologic time and to define general stratigraphic succession in accordance with the cycles of orogenic development, calling the classification, or the fundamental principle of correlation, a systematic arrangement of mountains, or orotaxis."

By the term mountains is meant not alone those geographic features which at the present time rise so majestically and conspicuously above the earth's surface, but also all of those remnantal structures which have been in the past prominent characters in the surface relief and which, geotectonically at least, are still mountains, though perhaps now completely planed off and buried beneath later sediments. With these old mountains the cycles of orogenic deveopment are properly regarded as extending from the time when the strata first were flexed, through the periods when they were bowed up, then planed off nearly to sea-level, and submerged, perhaps, until new degredational products

*Proc. Iowa Acad. Sci., Vol. VI, pp. 131-154, 1899.

†American Geologist, Vol. XVIII, pp. 289-303, 1896.

‡See; Science, N. S., Vol. XII, p. 146, 1900; also, Bull. Geol. Soc. America, Vol. XII, p. 175, 1901.

§Am. Jour. Sci. (4), Vol. XXI, pp. 296-300, 1906.

**American Geologist, Vol. XVIII, p. 298, 1896.

were deposited upon their upturned edges. The completed cycle of mountain-making is the measure of orotaxial chronology. The division-planes cutting the geological column into series, terranes and the smaller subdivisions are actually, as well as theoretically, the lines of unconformities and their representatives. In the cases of the more extensive features of discordant sedimentation they represent no doubt base-leveled surfaces, or peneplains.

As a concrete illustration there is probably no better one than that presented by the stratigraphy of the southern end of the Rocky mountains. There are in the geologic column more than a score of well defined terranes having the taxonomic rank of series. With possibly one or two exceptions they are all separated from one another by marked planes of unconformity. The most exact means of correlation over wide areas are given. Of not the least interest are the comparisons that are able to be made with the geologic sections both to the eastward in the Mississippi valley and to the westward in the Great Basin region.

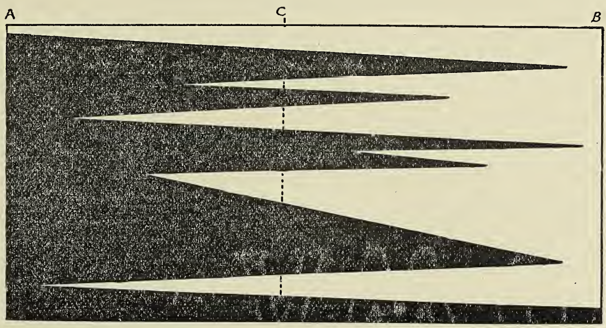

Figure 1. Oscillation of Continental Shore Lines.

In the domain of geologic correlation the most important deduction of recent years is that there is an erosional history of continental borders equally significant as that expressed in the sedimentary record. At best the sediments present only one-half of the stratigraphic history. The historical testimony of the fossils is not only fragmentary so far as the sediments in which they occur are concerned but it gives no suggestion of the erosional sequence of events which are of even greater consequence.

If we represent in diagram (Fig. 1) an ideal cross-section of a continental border, complete sedimental history stands at one side (section A), and complete erosional history at the other side (section C). In terms of the sediments the latter is an hiatus, or as the older text-books on geology call it a time-gap. The section B represents about as much of the complete history as the fossils ordinarily record. In reality the history which organic remains portray is merely that of faunal sequence, with no necessary relationships of physical episodes suggested; in its entirety it is only a small and imperfect fragment of the actual record of geologic events.

The zig-zag line may be further taken as indicating the oscillations of a shore-line; and also the course of the migration of a specific fauna during geologic time. At B, where the biologic section is made the point of special inquiry, the recurrence of faunas is graphically explained. More important than this is the weakness of the biotic method of geologic correlation that is shown; and the great strength and exactness of the correlative methods which are purely physical in character that are indicated.

The sedimentative section with its contained fossils stands for the continuous record; while the erosive history represents the rhythmic breaks which make possible exact correlation of terranes and general stratigraphic classification. The stratigraphic expression of the latter is the unconformity. This again is the outcome of diastatic, or diastrophic, movements, or more impressively and more readily recognizable in the field, the results of mountain-making changes upon the position of the shore-line of the ocean. Systematic arrangement of terranes on this basis is fundamental; it is strictly genetic; it is not dependent upon the often more or less fanciful interpretation of fossils; it is directly in harmony with the laws controlling sedimentation inself; it is the most practical and exact of any method yet devised; and it enables the votaries of geologic correlation to swing entirely clear of paleontology.

The nicety and rapidity with which the orotaxial principles act in practice are indicated by a number of concrete examples. In the Upper Mississippi valley the values of the different methods of geologic correlation have been recently specifically compared.*

In the Ozark region the shortcomings of the older methods of geologic classification have been pointed out.† Around the southern end of the Rocky mountains, in central New Mexico, the great value of the orotaxial method has been especially emphasized.‡ Its value has been determined in the unfossiliferous Tertiary deposits of the Death Valley region in eastern California and Nevada.§ Earlier Irving** strictly followed the method in correlating the Pre-Cambrian sequence of the Lake Superior region; and McGee†† applied its principles to the unfossiliferous formations of the Atlantic Coastal plain.

In the present advanced state of stratigraphical science, in which reconnaisance work is no longer needful over the large part of our country, it seems that we have reached a stage where classification of terranes should follow definite principles in accordance with the taxonomic ranks of the various geologic units, much in the same way that it is accomplished in botany or zoology. A dual geologic classification—one structural and the other biotic—is certainly superfluous. The biotic scheme may be advantageously eliminated entirely as it is now really done in practice by all except the old-school paleontologists.

We may arbitrarily recognize the larger divisions as worldwide time-divisions; and regard the sediments as deposited during certain eras or periods. The latter may also be advantageously subdivided into Early, Mid and Late classes, still retaining the time criterion. Below the taxonomic rank of period, or sub-period, however, geologic sections are provincial in character. The structure sequence of the region now becomes the most critical of the corre-

*Proc. Iowa Acad. Sci., Vol. X, pp. 105-107, 1903.

†Bull. Geol. Soc. America, Vol. XII, pp. 173-196, 1901; also, Ibid., Vol. XIII, pp. 267-292, 1902.

‡Am. Jour. Sci. (4), Vol. XXI, pp. 296-300, 1906.

§Trans. American Inst. Mining Eng., Bull. No. 34, pp. 867-903, 1909.

**U. S. Geol. Surv., 7th Ann. Rept., pp. 437-439, 1888.

††Cong. geol. international, 5me Sess., p. 164, 1903.

lative criteria. The series is all-important and not its time equivalent, which begins to have very vague definition even when different parts of the same geologic province are compared; and necessarily so in provinces with dissimilar histories. This plan gives prominence to the structural unit of geologic mapping, the lithologic formation, or terrane. Minor subdivisions of the latter may be delimited by the specific mineral peculiarities of the fossils.

By clearly distinguishing between geologic history and biotic history geologic correlation is placed upon a rational, genetic and philosophic foundation. Stratigraphy is immeasureably advanced.

CARBONIC COLUMN OF RIO GRANDE REGION.

BY CHARLES R. KEYES.

The character of the later Paleozoic succession in southwestern United States has radically modified our general ideas regarding carbonic history in America. As directly bearing upon this subject the Carbonic rocks of the New Mexican region are of exceptional interest. The Rio Grande section, if it may be so designated, is serially the most complete in the country. It is of great thickness. It contains many elements wholly unknown elsewhere on the continent. It furnishes full data with which to close the already prolix debate on the exact age and stratigraphic position of the uppermost Paleozoic beds of Kansas and other parts of the country. It is particularly important at this time as connecting the succession of the Mississippi province with that of the Far West. By contrast it emphasizes the insignificance of our eastern Carbonic representatives.

It was recently shown* that while few estimates on the maximum measurement of the Carbonic rocks of the Southwest ventured above 2,000 feet there really existed of these sediments in New Mexico the enormous thickness of more than 6,000 feet.

Although there have been many notes published on the Carbonic rocks of the Southwest there has never been any serious attempt to correlate the results of the various disconnected observations. Only lately have investigations of broad character made reasonably exact geologic correlation in the region possible. While it is, perhaps, as yet premature to venture beyond the provincial series in the detailed consideration of the Carbonic formations of the Rio Grande region, there are certain terranal names which have long been locally applied that may be used. Some of them were not, possibly, so exactly defined as they should have been originally; but this fact could hardly be a valid excuse for the proposal of new names on no better grounds than the old ones and the use of some of these old names in entirely different senses. From such course only confusion can come.

In its latest and most complete form the standard Carbonic section of the Rio Grande region, or of New Mexico, may be indicated as follows:

*Journal of Geology, Vol. XIV, p. 147, 1906.

GENERAL RIO GRANDE SECTION OF CARBONIC TERRANES.

	Time Divisions	Provincial Series	Formations	Rocks
CARBONIC PERIOD.	LATE	Cimarronian	Moencopie	Shales Sandstones
			Pecos	Shales
		Guadalupan	Capitan	Limestones
			Eddy	Sandstones
	MID	Maderan	Bernalillo	Shales
			Hueco (upper)	Limestones
			Oscuro	Limestones
		Manzanan	Mosca	Limestones
			Coyote	Sandstones
			Montosa	Limestones
			Sandia	Shales
		Ladronesian	Alamito	Shales
	EARLY	Socorran	Sierra	Limestones
			Lake Valley	Limestones
			Grande	Limestones

The presence of marked planes of unconformity between all of the several serial divisions is especially significant. It points to still other unknown and important representatives to make the American section complete. How great are the terranal representatives of these intervals can at present only be surmised. In northern New Mexico the unconformity plane between the Maderan and Cimarronian series is known, 200 miles to the southward, to be represented by over 3,000 feet of sediments. The remnants of the true coal-bearing series, corresponding to the lower productive coal measures of the Mississippi valley is believed to have been once of great thickness and extent. Under similar conditions an erosion interval north of the Ozark dome at the base of the Des Moines series is known to be represented farther south in central Arkansas by sediments the thickness of which is more than 10,000 feet.* In the Southwest the depositional equivalents of the Carbonic unconformities may equal or even greatly exceed in thickness that of the present known section.

The Socorran series corresponds in a general way to the lower part of the original Mississippian series of Missouri and Illinois. The Ladronesian, Manzanan, and Maderan series might be included in the world-wide Pennsylvanian division of the United States Geological Survey. The Guadalupan and Cimarronian series have no representation in the East; and the latter in the Mississippi valley only in western Kansas.

Three important subdivisions of the Socorran series have thus far been recognized.† These find their best development in the vicinity of Lake Valley, in southwestern New Mexico. There are good reasons for believing that other formations of this series exist nearby. These formations are the Grande, Lake

*The heavy lines indicate planes of unconformity. The Eddy sandstones may more properly belong to the Maderan possibly co-extensive with the Bernalillo shales and sandstones; there are reasons for believing that marked line of unconformity exists at the base of the Capitan limestone. All of the unconformities represent erosion epochs, except that between the Maderan and Manzanan which is apparently an overlap. There are several planes of unconformity in the Maderan section.

*Bull. Geol. Soc. America, Vol. XII, pp. 173-196, 1901.

†Trans. American Insti. Min. Engin., Vol. XXXIX, 1908.

Valley and Sierra limestones. The Lake Valley limestone, carrying the typical fauna of the Lower Burlington limestone was originally fully described by Springer.‡ Its northward extension to the Magdalena range, 100 miles away, was recently noted.§ Herrick's title** "Graphic-Kelly lime," for a part of this formation, that has crept into geologic literature during the past year was not intended to have exact geologic definition but merely local mining significance, referring to mines of that name. The Grande limestone appears to contain the fauna of the Chouteau limestone of Missouri. The Sierra limestone is a formation higher than any other of the Early Carbonic strata yet recognized in the Southwest. Gordon is mistaken in regarding all three of these divisions as the original Lake Valley limestone.

The only known Carbonic coal-bearing formation in the Southwest is included in the Ladronesian series. It is thought to be an extension or representative of the Arkansan series of the southern Ozark region. Being sharply delimited above and below by marked unconformity planes of erosional character it was doubtless once one of the most important formations of the region. Herrick,*, who first noted the beds, though not recognizing their true significance, referred them to the Upper Carbonic, but he subsequently was convinced that they were of earlier age. The series will doubtless be found to be wide-spread though possibly only in remnantal areas.† No one who has seen the two formations would think of correlating the beds of this series with any part of the Sandia shales. Its fauna and flora is a theme of great interest as it must be so unlike anything else in the West.

It is a matter of great surprise that the recent considerations of the beds constituting the Manzanan series should give rise to such a confusion of ideas as they have. It can only be accounted for by the cursory and incomplete character of the examinations during hasty reconnaisance work which has been the usual method in the region. The use of the term Manzanan is an attempt to preserve Herrick's title without introducing new names. To be sure, it was not at first definitely delimited, but since no other title for the beds in question has intervened there appears no good reason for abandoning the term, or for using it for a very different section having no elements in common with the first one.

As he himself has often in person explained, Professor Herrick in none of his published writings ever intended to formally propose any of the geolographic names which he used provisionally. The formal proposals of the necessary geologic titles and their definition was reserved for a special memoir which I believe was well along towards completion at the time of his sad demise. The intentionally informal character of the few geographic names he use from time to time is clearly indicated in all of his writings. His term Manzano, for example, is used in a number of different senses in as many different places; one referring to the gray limestones between the red-beds and the red quartzite at the top of his Sandia shales. The title Bernalillo shales, which I had suggested for the Mid-Carbonic red-beds, was acceptable to him and would have been used by him in his final memoir.

‡Am. Jour. Sci. (3), Vol. XXVII, p. 102, 1884.

§Proc. Iowa Acad. Sci., Vol. XII, pp. 169-171, 1905.

**American Geologist, Vol. XXXII, p. 311, 1904.

*Journal of Geology, Vol. XII, p. 242, 1904.

†Eng. & Min. Jour., Vol. LXXXI, p. 1129, 1906.

If the gray and blue limestones below the Bernalillo red shales of the Sandia district (Manzanan and lower Maderan) are to be thown together, which does not seem at all advisable, the term Magdalena Group as recently proposed* is clearly synonymic. Richardson's title of Hueco group† covers this section exactly, and has the great advantage of being at least recognizably defined.

The Maderan series appears to be separable from the Manzanan upon the same faunal and other grounds as the Missourian and Oklahoman series in Kansas. Its development is that of a three-fold sequence. As exposed in the north, in the Sandia mountains the main limestone member is only 400 feet in thickness. Higher and higher limestone beds come in southward until a maximum measurement of 3,000 feet is attained. This superior dark limestone formation, or median member of the series, is included in the Hueco formation of Trans-Pecos Texas. If the name Hueco is to be retained as a geologic title it may advantageously be applied to the median members as representing the main body of limestone of western Texas.

The third and youngest member of the Maderan series is composed of shales and sandstones having a characteristic red coloration. The title Bernalillo shales has been applied to them.‡ The fact that the "Red-Beds" are not of Permian nor Jura-Trias age is not a new discovery as lately announced by Lee.§ As early as 1900 Herrick** had found abundant fossils in these beds which were correlated with the so-called Permian (Permo-Carbonic) of Kansas. It must be remembered that all of this author's later references to the Permian are to this so-called Kansas Permian and not to the true Permian. About the first revision which my own preconceived notions of the region underwent when first I visited New Mexico in 1902, was that these Red-Beds of the Rio Grande region corresponded faunally to the Oklahoman series of Kansas. They were thus specifically correlated†† and their distinctness from the Kansas Red-Beds emphasized by the designation of the local title of Bernalillo shales. At the time it was thought that the upper one-third of the red-beds section might be a part of the Cimarronian series; but it was soon afterwards discovered that over thi part of the region of central New Mexico both the Kansas Red-Beds and the Triassic Red-Beds were absent.* In the section east from the Manzano mountains, down the Rio Pecos and Canadian river valleys there are thus found three great red-beds formations imposed upon one another with apparently no sharp planes of separation and belonging to three distinct geologic ages. To avoid confusion I have tried to be always very careful to apply the title Red-Beds only to this great sequence. There are in the region extensive Cretacic "red-beds," which I have always referred to as the Pink beds, or Tertiary "red-beds," and farther south great Devonian "red-beds," which I have not designated at all.

To further complicate the Red-Beds problem southward from the Sandia locality the sandy materials rapidly increase and the red coloration fades, as it does in the Red-Beds region of Kansas and Oklahoma. In the 150 miles

*Journal of Geology, Vol. XV, p. 812, 1907.

†Univ. Texas Min. Sur., Bull. 9, p. 32, 1904.

‡Ores and Minerals, Vol. XII, p. 48, 1903; also, Rept. of Governor of New Mexico to Secretary of Interior, for 1903. p. 339, 1904.

§Journal of Geology, Vol. XV, pp. 52-58, 1907.

**Journal of Geology, Vol. VIII, p. 116, 1900.

††Loc. cit., p. 339, 1904.

*Amer. Jour. Sci. (4), Vol. XX, pp. 423-429, 1905.

which separate the Sierra Oscura and the Guadalupe range, which I have not yet been over thoroughly, a grave question arises as to what becomes of the red Bernalillo shales and sandstones. I have fancied sometimes that the 1,500 feet of Richardson's Delaware Mountain sandstone (Eddy sandstone) which immediately overlies the dark Hueco (Maderan) limestones is the southern continuation; but of this there is as yet no strong proofs.

I had also thought that I had traced the Cimarronian Red-Beds of western Kansas and northwestern Texas up the Canadian River valley and down the Pecos valley, around the great escarpment of the Llano Estacado, to the vicinity of the Guadelupe mountains where presumably they rested on the Guadelupe limestone. While on account of the extensively faulted character of the area it may take further field work in order to determine this point beyond all question there has yet appeared no valid grounds for believing that these Red-Beds underlie the Guadalupe limestones.

The existence of a dark limestone, 800 feet in thickness, above the Bernalillo shales, as urged by Lee* and by Gordon† I very much question. There will have to be very much better testimony adduced before their ascertion can be accepted. My own observations have been strongly to the contrary. I am quite familiar with all of the localities mentioned by both of the authors named. In every instance there seems to be very clear evidences of profound faulting which has raised, as it were, the lower limestones above the outcropping level of the red shales. In the San Filice range, east of Socorro, the fault has been tested by the drill and a displacement of nearly 1,000 feet found, yet along the faultline there is practically no bending of the strata. Similar apparent faulting back of the Sandia and Manzano ranges, where Lee states that the great upper dark limestone is missing, brings the lower limestones above the level of the same shales, in the same way as it does in the Caballos, Oscura and San-Filice ranges. Small wonder is it that Girty comments with surprise upon the similarity of the fossils which were collected for him from the limestones beneath the Bernalillo shales and the alleged limestone above.

Late Carbonic time is represented in the Rio Grande region by the great Guadalupan series of limestones, the faunas of which were early described by Shumard‡ and later by Girty§, but which have no counterparts elsewhere on the American continent. Their affinities are with the original Permian series of Russia.** The other Late Carbonic representative is the true Cimarronian series of Red-Beds of Kansas, separated from the Triassic red-beds by marked unconformity††.

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*Journal of Geology, Vol. XV, p. 54, 1907.
†Ibid., p. 816, 1907.
‡Trans. St. Louis Acad. Sci., Vol. I, p. 280, 1860.
§Univ. Texas Min. Sur., Bull. 9, p. 40, 1904.
**Journal of Geology, Vol. VII, pp. 321-341, 1899.
††Am. Jour. Sci. (4), Vol. XX, pp. 423-429, 1905.

THE HYSTERESIS LOOP.

BY D. W. MOREHOUSE AND HARRY RAY WOODROW.

It is not proposed to introduce a new method for the determination of the hysteresis loop, but to introduce some advantageous modifications.

The method is similar to the ring ballistic method outlined by Dr. R. A. Millikan. This method has the advantage over the old magnetometer method in that the lines of force are continuous through the iron. It cannot be used however if the iron is hard and causes any creeping.

The revolving commutator is a plain application of the mercury cup commutator with which we are all familiar. The variable resistance is an application of the common resistance box, using knife edge switches in place of the plugs. This gives a continuous current which can be increased or diminished by the throw of the switches.

The current was increased by small steps and the value of the current taken by a potentiometer as the most accurate ammeter will not detect the small changes. The induced current was measured by the throw of a ballistic galvanometer and the throw evaluated by means of the earth inductor.

The value of the magnetizing field increased more rapidly than the inductance until (H) reached the value of about two gauses, then the inductance increased much faster than (H), until (H) reached the value 5.068 gauses and from this point the ratio of (B) to (H) became smaller and smaller and approached zero as a limit making the curve approach a straight line parallel to the X axis. As the current decreased the curve crossed the Y axis at (B) = 10,486 lines, giving 73.3 per cent for the retentivity. When the current was reversed the curve crossed the X axis at — 3.03 gauses which is the coercive force.

DATA FOR THE HYSTERESIS LOOP.

V equals .570747.
Radius of ring, 4. 75 cm.
Coil, 590. turns.
Test coil 75. turns.
Earth inductor 1000 turns.
Radius of E. In. 7.7 cm.
Radius of testc. .717 cm.
Mean d was 8.36 cm.

I	d	Sum. d.
+.055	+3.58	+ 3.58
.063	1.05	4.63
.072	2.00	6.63
.085	5.08	11.71
.095	4.30	16.01
.108	6.00	22.01
.124	6.68	28.69
.143	5.80	34.49
.170	5.30	39.79
.204	5.28	45.07
.266	5.70	50.77
.353	5.69	56.46
.472	4.68	61.14
.620	3.60	64.74
.718	1.95	66.69
.621		

H	B	u
3.553	7230.5	2036.6 max.
5.068	9453.0	1865.5
17.61	13920.0	790.3

I	d	Sum. d.	I	d	Sum. d.
+.621	— .08	+65.84	—.608	+ .80	—74.80
.472	1.30	64.59	.467	1.30	73.50
.350	1.50	63.09	.348	2.45	71.05
.264	1.55	61.54	.261	1.40	69.65
.204	1.75	60.19	.203	1.30	68.35
.171	1.10	69.09	.168	1.02	67.33
.143	.88	58.21	.143	.80	66.53
.124	.70	57.51	.124	.70	65.83
.108	.60	56.91	.110	.60	65.23
.097	.55	56.36	.096	.55	64.68
.086	.50	55.86	.086	.49	64.19
.072	.50	55.36	.071	.90	63.29
.062	.70	54.66	.064	.62	62.67
.055	.45	54.21	.054	.42	62.25
.000	5.10	49.11	.000	5.20	57.05
—.055	—9.00	—40.11	+.054	+9.42	—47.63
.062	1.60	38.51	.063	1.70	45.93
.073	3.00	35.51	.073	3.18	42.75
.087	6.40	29.11	.087	6.50	36.25
.098	5.68	23.43	.097	5.67	30.58
.109	10.33	13.10	.109	10.40	20.18
.125	15.90	— 2.80	.124	15.90	+41.28
.142	17.30	20.10	.142	17.45	13.17
.167	13.25	33.36	.169	13.00	26.17
.205	10.70	44.05	.204	10.27	36.44
.260	9.84	53.89	.262	9.30	45.74
.350	7.58	61.47	.350	8.02	53.76
.468	6.50	67.97	.466	6.10	59.86
.609	5.50	73.47	.606	4.30	64.16
.714	2.13	75.60	.709	2.20	66.36

THE GOOGLER PRIMARY BATTERY.

BY HARRY RAY WOODROW.

The cell furnished us by the Battery Company was of the two fluid type. The exciter was sulphuric acid and zinc and the depolarizer was principally nitric acid. It resembled very much the Groove and Bunsen cells but differed in the depolarizer, which contained ferric sulphate. The carbon was placed inside the porous cup surrounded by 450 c. c. of the depolarizer. Outside this was 2,000 c. c. of sulphuric acid and a round cylinder of zinc. The mercury served the purpose of keeping the zinc amalgamated and also in making contact with the external circuit.

In the chemical analysis I found iron and a slight trace of zinc in the depolarizer but no metal in the exciting fluid. Both solutions were acid which proved to be nitric and a small amount of sulphuric in the depolarizer and only sulphuric in the exciting fluid. It was at once evident that the iron in the depolarizer was in the form of ferric sulphate which gave the solution its brown color. It is to be noted that this brown color turned to green as soon as the action began in the cell. The hydrogen reduced the ferric sulphate and then the nitric acid oxidized the ferrous sulphate. The object of this was to make the action milder and fewer nitrous fumes would escape.

The quantitative analysis of nitric acid is best determined by titration and the sulphuric acid is determined very nicely by precipitating the sulphate with barium chloride and weighing the precipitate as barium sulphate. From this data the amount of sulphate (s) can be determined by the formula:

$$s = abd \div ce \ldots\ldots (1)$$

where (a) is the molecular weight of (s), (c) the molecular weight of the weighed precipitate, b the weight of the precipitate, (d) the total volume of the solution in the battery, and (e) the amount taken for determination. The sulphate is not all in the form of sulphuric acid but some of it is combined with the iron and zinc. The iron was determined by precipitating it as ferric hydrate and weighing it as ferric oxide. The amount of iron is found by formula (1) by usng the values of a, b, and c which correspond to iron and ferric oxide. Formula (1) may be simplified by the use of the chemical factor (f) which is equal to a—c.

$$\log. (s) = \log. (b) + \log. (f) + \log. (d) - \log. (e) \ldots\ldots (2)$$

The zinc was determined by precipitating it as a corbonate and weighing it as an oxide. After the amount of zinc and iron is known it is a simple matter to determine the amount of sulphate (k) combined with them by the use of the formula:

$$k = os \div g \ldots\ldots (3)$$

where o is the molecular weight of sulphate, s the same as in formula (2) and g the atomic weight of the metal (s).

We can now subtract the amount of sulphate combined with the iron and zinc from the total amount and the remainder will be the amount combined with hydrogen to form sulphuric acid.

$$j = kl \div m \qquad (4)$$

given the amount of sulphuric acid; when k is the amount of available sulphate, l the molecular weight of sulphuric acid, and m the molecular weight of sulphate.

As we have the amount of sulphuric acid we can now proceed to find the amount of nitric acid in the solution. As was said before this can be done by titration with a hydrate, but we must remember that the sulphuric acid will require some of the hydrate to neutralize it. I therefore subtracted the amount of potassium hydrate, as I used potassium hydrate for titration, required to neutralize the sulphuric acid in the portion used. The remainder was the amount used in neutralizing the nitric acid. Methyl orange was used as an indicator as it changes color from the acid to neutral solution. The amount of nitric acid (N) is determined by the following formula:

$$N = ACEd \div Be \qquad (5)$$

A is the molecular weight of nitric acid, B the molecular weight of potassium hydrate in one c. c., C the number of c. c. of potassium hydrate used against nitric acid, and d and e the same as in formula (1).

We now have determined the amount of zinc sulphate or zinc, ferric sulphate or iron, sulphuric acid, and nitric acid in the depolarizer. The outer solution was much easier analyzed as it only contained sulphuric acid at first and later on zinc sulphate and sulphuric acid. I determined these the same way as I did in the depolarizer.

In order to find the chemical action it was necessary to take out ten c. c. of both solutions every six hours and analyze it. This was done and the results are tabulated in data 3.

A very essential thing to know about a cell is its action on open circuit. I let the cell stand for forty-eight hours on open circuit and the action was slight and much more in the zinc and sulphuric acid than on the nitric acid, there being 25.2 grams of zinc dissolved, 36 grams of sulphuric acid used and 1.4 grams of nitric acid reduced.

I took the E. M. F. of the cell by means of the Leeds Norturup potentiameter, type K, and found it to be 1.8935. The next step was to find the internal resistance of the battery in order to know what external resistance would give a current of about nine amperes. The condenser method was used and the internal resistance B found by the formula:

$$B = S(d'-d'') \div d'' \qquad (6)$$

Where S is the resistance in shunt, d″ the throw on charge or discharge shunted, and d′ the throw on charge or discharge. The throw is proportional to the voltage, and d′ represents the E. M. F. and d″ represents the P. D. with an external resistance S. Thus we see this method is only a simplified one of the regular fall of potential method, whose formula is:

$$B = ((E\text{-}V) \div V)\ R \text{ or } B \text{ equals } (E\text{-}V) \div C \qquad (7)$$

I found the ohmic resistance to be .0710. I used the condenser method in finding the internal resistance on recovery and the fall of potential method when the battery was running on closed circuit.

Having found the internal resistance (B) to be .0710, I used the formula:

$$c = v \div (r + b)$$

in order to find the value of r necessary to make c about nine ampers. I then put r to about this value and measured it exactly with the postoffice bridge.

I measured the E. M. F., the P. D. and current by the potentiameter every hour until the battery was run down. The E. M. F. and P. D. are measured directly on the potentiameter while the current is measured by measuring the potential difference of .01 of an ohm resistance in the circuit. Then

$$c \text{ equals } v' \div r = v' \div .01 \text{ equals } 100v' \ldots\ldots (8)$$

These results are tabulated in data 2 together with the temperature of the room, the internal and external liquid, and the internal resistance as figured out by formula (7).

Having the chemical action, we are now in a situation to calculate the E. M. F. when 96,550 colombs of electricity possess one gram equivalent of each ion. One colomb is 10^{-1} c.g.s. units and one volt is 10^{8} c.g.s. units. Therefore one colomb of electricity will correspond to 10^{7} E ergs and 96,550 colombs will equal to $96{,}550 \times 10^{7}$ E ergs. We will now assume that all the energy due to chemical action is converted into electrical energy. If we let m equal the amount of heat evolved by the action of sulphuric acid on one equivalent of zinc and n equals the amount of heat evolved by the reduction of the acid. Then the work done in ergs by the chemical action is $(n+m)\ 4.2 \times 10^{7}$ for 4.2×10^{7} is the value of a calorie in ergs. As we have both the electrical energy and chemical energy in ergs and assume them to be equal, we have

$$96{,}550 \times 10^{7} E' = (n+m) 4.2 \times 10^{7}$$

Thus $$E' = ((n+m)\ 4.2) \div 96{,}550 \ldots\ldots (9)$$

One gram atom (63gms.) of zinc dissolved in sulphuric acid evolves 38,066 calories of heat. Zinc is a diad and consequently one equivalent (63÷2 gms.) evolves 19,033 calories of heat and is the value of m.

In taking up the value of n, a more difficult problem confronts us. The nitric acid is reduced in several different stages. The two principal equations of formations are:

$$HNO_3 + H_2 = HNO_2 + H_2O + 41013 \text{ calories.}$$

and $$HNO_3 + H = NO_2 + H_2O + 26966 \text{ calories.}$$

Besides the reduction of the nitric acid in these two ways, the brown fumes of nitrogen pentoxide showed that some of the nitric acid was broken up into nitrogen pentoxide and water.

$$2HNO_3 = N_2O_5 + H_2O - 7330 \text{ calories.}$$

We do not know the amount of each formed, but we can calculate the average during the interval of six hours. We know the quantity of zinc (x) dissolved and the quantity of nitric acid (P) used. It will be necessary to consider that just two of these actions occur at once and, as HNO_2 will not be found when N_2O_5 is liberated, this will be permissible.

If we let x equal the amount of zinc dissolved, y the hydrogen liberated, P the HNO_3 used, r the HNO_3 reduced to HNO_2, and a the hydrogen liberated which reduces the HNO_3 to HNO_2. Then P-r equals the HNO_3 reduced to $NO_2 + H_2O$ and H-a the hydrogen used with it.

Then $$65 \div 2 = x \div y \ldots\ldots (10)$$

$$63 \div 2 = r \div a \ldots\ldots (11)$$

$$63 \div 1 = (P-r) \div (y-a) \ldots\ldots (12)$$

Eliminating a and y equation (10), (11) and (12)

$$r = 126x \div (65-P) \ldots\ldots (13)$$

If r comes out minus we consider that no HNO_2 is formed and proceed to determine the HNO_3 used for N_2O_5 and NO_2. To determine this we calculate the amount of HNO_3 used for all the zinc and subtract that from the HNO_3 used and that leaves the HNO_3 decomposed into H_2 and N_2O_5. These results are tabulated in data No. 4.

As we have the ratio of the different reductions of the HNO_3 we can determine n and then the calculation of E′ is very simple by subtracting in equation (9). This is done for the five intervals of time and tabulated in first part of data No. 7.

In calculating the E. M. F. (E′) of the cell at different times we have not taken into consideration the temperature coefficient (de|dt) which must enter into the equation for the time calculated E. M. F. We must now direct our attention to the temperature coefficient (de|dt).

In doing this we will let H′ equal to the amount of heat supplied (in ergs) at the temperature T′ and H″ the heat subtracted at the temperature T″. Then

$$(H'—H'' \div H' = (T'—T'') + T'$$

H′—H″ is the quantity of heat used and is equal to O″ (E′—E″); where O″ equals the units of electricity passed at T′ and T″ and E′ and E″ the E. M. F. at T′ and T″.

Therefore O″ (E′—E″) ÷ H′ = (T′—T″) ÷ T′

thus H′ = O″ T′ (E′—E″) ÷ (T′—T″).

(E′—E″) ÷ (T′—T″) is the rate of change of the E. M. F. of cell with temperature and we will designate it by de÷dt. By letting O″ equal to unity the equation reduces to

$$H = T\ (de \div dt) \quad \ldots\ldots (14)$$

Which is the quantity of heat converted into electrical energy during the passage of a unit quantity of electricity. It is to be noted that de|dt carries its sign. That is it is plus if it increases with temperature and minus if it decreases with temperature.

If H‴ is total amount of heat produced by chemical action when one unit quantity of electricity passes through the cell. Then

$$H''' + p = E$$

When H‴ and p are in ergs.

Consequently, $H''' + de \div dt = E \quad \ldots\ldots (15)$

And E is the time calculated E. M. F. of cell temperature T on the absolute scale.

Now we will proceed to find de|dt, which is necessary in calculating the time E. M. F. We will represent the current by c and the P. D. at the terminals of cell on closed circuit with external resistance r by e. Then the heat developed in the external circuit in the time t is equal to aect calories, when (a) equals .2387, which is the value of one joule in calories. The heat developed within the cell itself in the time t, by the passage of the current (c) is $ar''c^2t$ where r″ is the internal resistance of the cell. Therefore $(ar''c^2t + aect)$ is the amount of heat developed by the passage of ct units of electricity.

$$E = se + cr''$$

multiply by act

$$acEt = acet + ac^2rt \quad \ldots\ldots (16)$$

It will be noticed that each side of this equation represents the energy transferred into heat.

If w represents the amount of heat taken up by the cell and also the amount radiated; then

$w = ar^2c''t—actde|dt\ t$ ....(17)

Eliminating $ar^2c''t$ in equation (16) and (16) and (17)

$acEt = acet + w + acTde|dt\ t$

Hence $de \div dt = acEt — acet — w|aTct$

And $de \div dt = E — e — ar \div act(T)$ ....(18)

Before we can continue any further in finding de÷dt, we must find the value of w, which represents both the radiated heat and the confined heat. The first step in finding w is to find the water equivalent of the battery, which is done in the following manner:

Weight of jar..........	1451	gms.	Sp. H.	.198	W.E. 287.3
Weight of carbon........	956.3	"	"	.144	" 135.2
Weight of zinc..........	1907.2	"	"	.093	" 177.4
Weight of porous cup.....	565.4	"	"	.206	" 116.5
Weight of Fe_2SO_4........	12.39	"	"	26.4	" 2.1
				149	
Weight of ZnSO4.........	25.2	"	"	26.4	" 4.13
				161	
Weight of H_2SO_4..........	288.33	"	"	.269	" 77.69
Weight of HNO_3..........	353.7	"	"	.303	" 107.20
Weight of H_2O...........	2124.15	"	"	1.	" 2124.15
Total water equivalent..........					3031.62

The specific heat of a sulphate is 26.4÷M where M is the molecular weight of the compound.

We now have the water equivalent of the battery and the confined heat is the product of water equivalent and change in temperature.

The radiation constant (a) is the next essential to determine. The battery was heated to a few degrees above the temperature of the room. The temperature of the battery was now 27° and the room 23°. The temperature fell to 25.25° in 45 minutes. Then the total amount of heat lost per hour was 1.75x3031.62÷.75 which is 7069 calories. Then the quantity of heat (Q) radiated, is

$Q = a(T'^4 — T^{\circ 4})$ ....(19)

where T′ and T° is the temperature of the battery and room on the absolute scale.

$$7069 = a\ (8001000000 — 7727000000)$$

$$\log a = 5.4115 — 10$$

Now in finding the heat radiated we have a, T′ and T° given and solve for Q. The value of w is thus figured for the five intervals of time and tabulated in data No. 5.

As we have w we can now substitute in equation (16) and find de÷dt. This is done and tabulated in data No. 6.

We now have everything to make a complete calculation of the E. M. F.

E. M. F. = E′ + Tde÷dt.

The most accurate way in determining the efficiency of a battery is to take the total amount of electrical work done in comparison with the total amount of chemical work done. .

The accompanying curves are drawn according to the accompanying data. Curve 3, fig. 1, plate 1, is the E. M. F. on open circuit and was very steady after the first few minutes until about three forty, when it suddenly drops. This drop is due to polarization and by looking at data No. 4 we will see that there is more hydrogen liberated at this point than the nitric acid was able to take up. The curve runs along very smoothly until the last hour, where it drops a little and also at this point the nitric acid is practically all gone. The recovery curve 2, fig. 1, plate 1, came up very rapidly at first and then slowly rose until it reached the starting point, where it was very near the calculated voltage of the cell when HNO_2 is formed. Curve 1, fig. 1, plate 1, which is the E. M. F. curve on running down again, dropped so fast that it was difficult to take the E. M. F. readings. It dropped to the level of the E. M. F. when the recovery curve started and then gradually fell.

The potential curve (18) fig. 2, plate 1, agrees very well with E. M. F. curve if we consider curve (c) which is the internal resistance curve. The P. D. falls gradually while the E. M. F. runs along very near the same level. This fall is due to the use in the internal resistance. This curve runs along with the calculated E. M. F. curve (4) fig. 1, plate 1, until it reaches the point of polarization. The drop in the sixth hour is due to the rise in temperature at that time, shown by curve (9) fig. 2, plate 4, for de÷dt is negative at this point.

The current curve (17) fig. 2, plate 2, falls faster than P. D. curve because the internal resistance here again enters into the equation. The drop at the sixth hour here is the same as in the P. D. curve, as would be expected.

The internal resistance curve (6) fig. 1, plate 2, rises until the nineteenth hour when there is a drop. The resistance that is above the level of curve (7) fig. 1, plate 2, which is the recovery curve of the internal resistance, is due to polarization. The drop here is due to the fact that hydrogen is not liberated so fast and the nitric acid can take care of it better. The internal resistance falls immediately on recovery which shows very plainly the polarization resistance.

The wattage curve (8) fig. 1, plate 4, is a combination of the P. D. curve and the current curve and has their respective characteristics. The temperature curve (9) fig. 2, plate 4, of battery represents the heat developed within the battery and it together with the temperature of room shows the heat radiation.

The specific gravity curves (11) fig. 2, plate 3, and (12) fig. 2, plate 3, resemble the HNO_3 curve (13) fig. 1, plate 3, and the zinc curve (16) fig. 1, plate 5. The reason for this is the fact that the specific gravity of nitric acid is proportional to its per cent. The action through the porous cup changes this a little and at the end of the specific gravity curve it rises a little, due to the heavier zinc solution coming in. In the outer solution the specific gravity raises in proportion to the amount of zinc brought into the solution.

The hydrogen liberated curve (14) fig. 1, plate 3, and the zinc consumed curve (16) fig. 1, plate 5, are the same relative curves as the hydrogen liberated is proportional to the zinc consumed. These are also the same as the H_2SO_4 curve only inverted.

The zinc consumption curve (21) fig. 2, plate 5, against the wattage represents the zinc efficiency and is equal to the H_2SO_4 curve (20) fig. 2, plate 5, only inverted. This is true because the amount of chemical work done by the zinc and H_2SO_4 is proportional to the zinc consumed. The wattage, that is watt hours in the case, is the electrical work done. The HNO_3 decomposed curve

(19) fig. 2, plate 5, does not exactly represent the work done because it decomposes in different ways and evolves different amounts of heat.

The heat watt curve (23) fig. 2, plate 6, is the efficiency curve as x represents the total chemical heat and y the watt hours. Curve (22) fig. 1, plate 6, is the temperature coefficient curve plotted against the time. It starts out a plus due to the heat taken up in formation of N_2O_5 and soon changes to a minus and then contrives to fall.

The cell is of no practical good for closed circuit work after the nineteenth hour when polarization sets in. But the cell may be filled with the solution again and be nearly as good as new. It is to be noted that the rougher the zinc gets, due to the chemical action, the higher the local action is. This is due to the fact that the rough dirty zinc will not keep amalgamated.

DATA NO. 1.

PHYSICAL PROPERTIES.

Weight of zinc .... 1975.7 grams
Weight of carbon .... 956.3 grams
Weight of jar .... 1787.4 grams
Weight of porous cup .... 565.4 grams
Weight of mercury .... 408.6 grams
Inner Sol., volume 450 cc spgr..1.3824
Outer Sol., volume 2000 cc spgr...1.1023
Surface of carbon ....141.99 sq. inches
Surface of zinc ....188.49 sq. inches

DATA NO. 2.

ELECTRICAL PROPERTIES.

Time	E. M. F.	P. D.	C.	Int. Res.	Watts	Int. t	Ext. t	R'm. t
9:40	1.8435	1.2667	9.252	.06532	11.61	6.00	6.00	7.50
10:40	1.7650	1.1814	8.662	.06982	9.89	8.00	8.00	7.00
11:40	1.7646	1.1806	8.2170	.07112	9.68	9.00	8.50	5.50
12:40	1.7444	1.1502	7.973	.07447	9.17	9.00	8.50	4.50
13:40	1.7412	1.1345	7.752	.07820	8.76	9.50	8.50	5.75
14:40	1.7385	1.1336	7.724	.09100	8.72	9.50	9.00	5.00
15:40	1.7323	1.0753	7.144	.09169	7.64	10.00	9.00	5.00
16:40	1.7205	1.12187	7.404	.09616	8.28	11.00	9.50	4.75
17:40	1.7200	1.0511	6.951	.10520	7.29	10.25	9.00	4.50
18:40	1.7110	1.0242	6.621	.1099	6.75	9.50	8.00	4.00
19:40	1.7158	.9923	6.578	.1076	6.52	11.00	11.80	7.00
20:40	1.7092	.9902	6.667	.1199	6.69	12.00	12.00	7.00
21:40	1.7058	.9741	6.091	.1312	5.93	13.20	12.00	8.00
22:40	1.7020	.9220	5.934	.1496	5.47	14.8	13.00	9.00
23:40	1.6891	.8684	5.448	.1656	4.72	14.8	13.50	9.00
24:40	1.6640	.8247	5.063	.1782	4.17	16.00	14.50	11.00
1:40	1.5977	.7950	4.703	.2075	3.73	17.00	16.50	11.00
2:40	1.5977	.7555	4.051	.2985	3.05	18.00	17.00	12.00
3:40	1.5754	.6993	2.929	.3141	2.04	19.00	18.00	14.00
4:40	1.2900	.5152	2.4695	.3148	1.26	19.00	18.00	14.00
5:40	.5550	.3138	1.893	.1274	.59	19.00	18.00	16.00
6:40	.4846	.2108	1.024	.2655	.215	18.60	17.80	15.50
7:40	.4598	.798	.958	.2388	.171	18.00	17.00	14.50
8:40	.4189	.1471	.938	.2897	.138	19.00	18.00	16.00
9:40	.4300	.1475	.872	.3119	.128	19.50	19.50	18.00
10:40	.3277	.0952	.7285	.3194	.070	20.00	19.00	16.00

RECOVERY ON OPEN CIRCUIT.

Time	E. M. F.	Internal Resistance by condenser method Time	Int. Res.
10:40	.3277		
10:59	.3918	10:57	.275
11:21	.4374	11:13	.174
11:34	.7485	11:27	.082
11:53	.7485	11:48	.195
12:38	1.0832	12:39	.202
13:38	1.2720	13:40	.177
14:54	1.4133	14:55	.206
16:12	1.4791	16:15	.201
17:55	1.5416	16:15	.235
8:30	1.7350	8:30	.2605
11:30	1.7410		

BATTERY ON CLOSED CIRCUIT.

Time	E. M. F.	P. D.	Current
11:30	1.7410	.2254	1.185
11:35	.8786	.1330	1.137
12:00	.3565	.1070	.694
17:50	.2730	.0351	.3010
8:00	.1455	.0730	.0021

Watt Hours Complete 132.382
Amount of work done in Joules..476575.200

DATA NO. 3.

CHEMICAL DATA.

	Inner sol.			Outer sol.				
Time	H_2SO_4	Zn	HNO_3	$FE_2(SO)_{43}$	Spgr.	H_2SO_4	Zn	Spgr.
9:40 Wed	8.241	00.0	358.1	12.39	1.3824	316.09	000.0	1.1023
9:40 Fri		2.0	353.7		1.375	280.09	23.2	1.1216
15:40		9.6	105.0		1.1555	183.7	87.3	1.1634
21:40		21.7	37.8		1.1007	102.59	145.2	1.203
3:40		26.3	12.6		1.0947	46.09	159.6	1.261
7:40	2.06	30.5	4.88		1.0947	26.39	162.1	1.280
19:40	1.13	31.6	.914		1.0951	16.99	162.9	1.284

DATA NO. 4.

DETERMINATION OF CHEMICAL HEAT.

Time	Zn in sol X	HNO_3 used P	N_2O_5 C	NO_2 P−r	HNO_2 r	Heat of H_2SO_4+Zn	Heat of HNO +H	Heat Compl't
5:40	62.1	248.7	128.7	120.	00.0	36470.	43871.	80341.
21:40	57.9	67.2	00.00	22.4	44.8	34010.	38755.	72765.
3:40	40.7	25.2	H. Unc. .42	00.0	25.2	23890.	16410.	40300.
7:40	6.7	7.72	00.00	2.45	5.27	3934.	4481.	8415.
10:40	1.9		00.00	.24	3.72	1115.	2524.7	3739.
Total heat								205560.

DATA NO. 5.

DETERMINATION OF W.

Time	Temp. of B.	Temp. of R'm.	Heat Rad.	Heat in B.	Total Heat W
9:40—10:40	6. - 8.	7.25	—1754	6063.2	4309.2
15:40—16:40	9.5-10.25	4.9	+11150	2273.6	13423.6
20:40—21:40	12. -12.6	7.5	+11400	1818.9	13218.9
3:40— 4:40	18.5-18.5	14.	+11150	3000.0	11150.0
8:40—10:40	17.5-18.5	16.	+2579	3031.6	5610.6

DATA NO. 6.

DETERMINATION OF HEAT COEFFICIENT DE÷DT.

Time	E	P. D.	C.	T	W	de÷dt
9:40	1.8042	1.2240	8.907	280 00°	4309.2	+.000062
15:40	1.7264	1 0985	7.324	283.25°	13423.6	+.00053
21:40	1.7075	.9821	6.379	285.60°	13218.9	+.00060
3:40	1.4327	.6072	2.699	291 50°	11150.0	+.00136
8:40	.4194	.1473	.905	292.00°	5610.6	+.00237

DATA NO. 7.

DETERMINATION OF E. M. F.

Time	N	M	E	de÷dt	E. M. F.
9:40	23057.	19033	1.830	+.0000625	1.8475
15:40	22659.	19033	1.813	—.00053	1.6001
21:40	20506.	19033	1.719	—.00060	1.4147
3:40	21625.	19033	1.767	—.00136	1.3863
7:40	20840.	19033	1.735	—.00237	1.0135

DATA NO. 8.

TOTAL EFFICIENCY.

From Data No. 2—
Amount of electrical work done....476575.2 joules
From Data No. 4—
Total chemical heat ....205560. calories
Total chemical work ....861200. joules
Total efficiency ....55.34 per cent

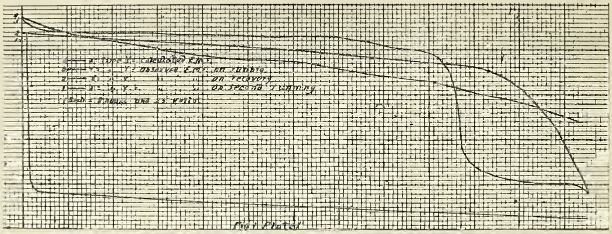


Fig 1 Plate 1

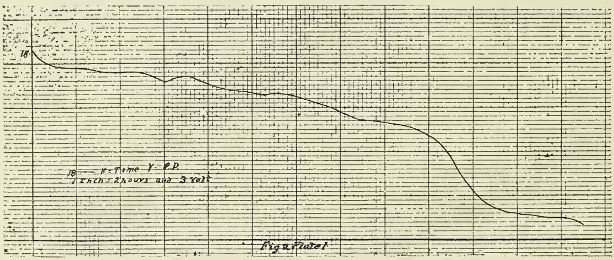


Fig 2 Plate 1

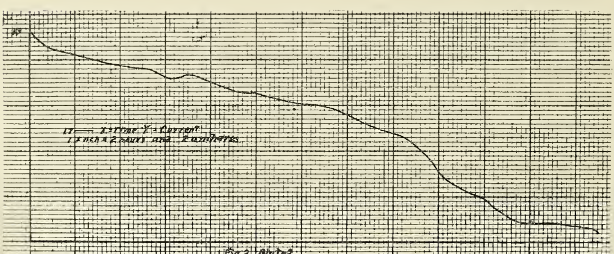


Fig 2 plate 2

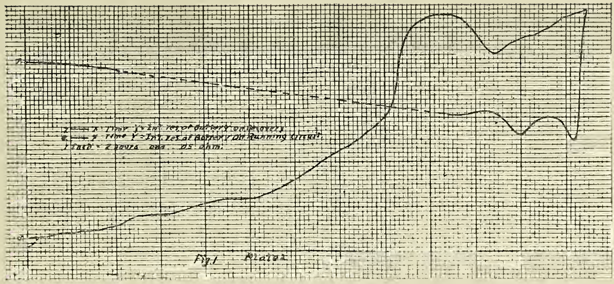
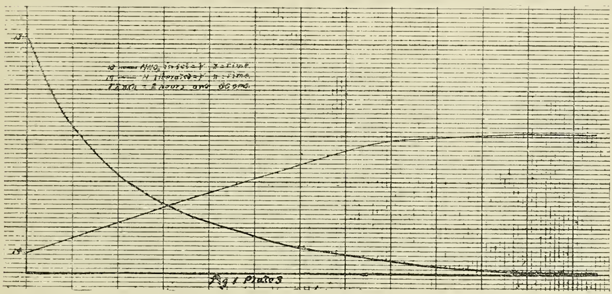


Fig 1 Plate 2



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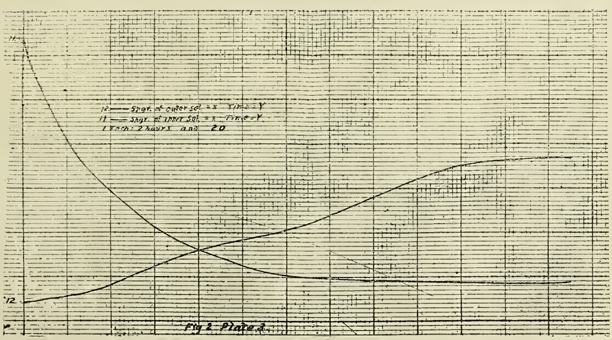
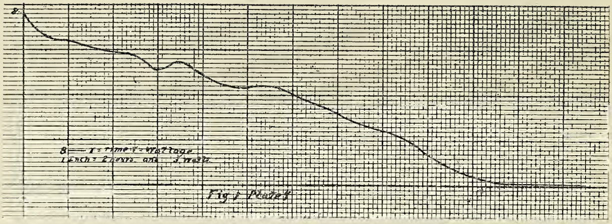


Fig 2 Plate 3



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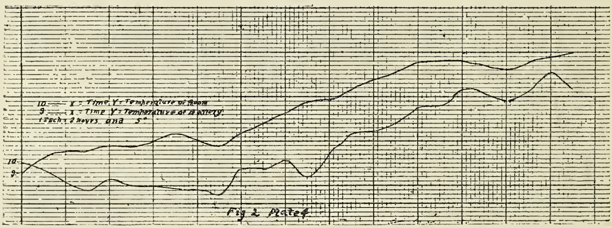


Fig 2 Plate 4

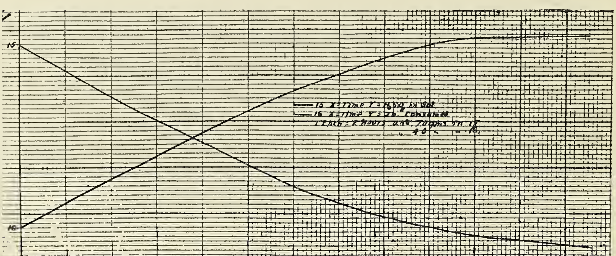
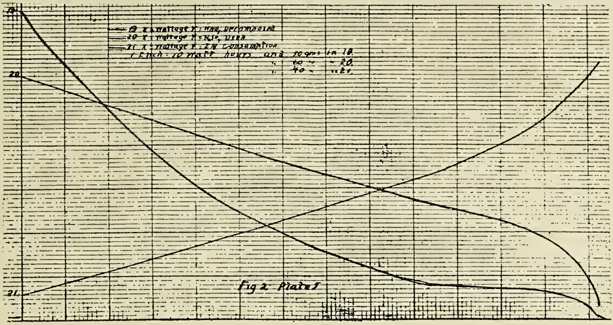
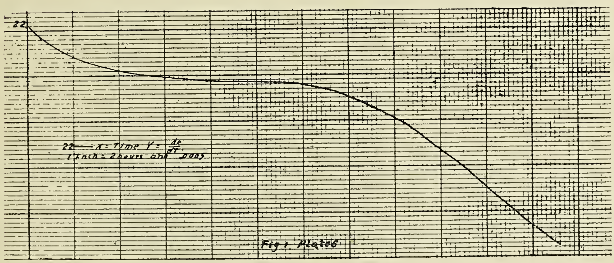
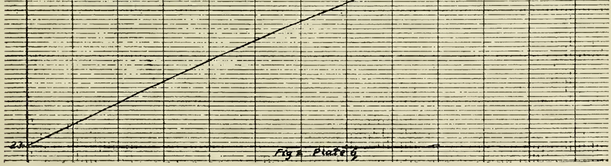


Fig 1 Plate 5


19
20
21
Fig 2 Plate 5


22
22 — X = Time
Fig 1 Plate 6


23 — X = Chemical heat Y = Watt hours
23
Fig 2 Plate 6

EFFECT OF TEMPERATURE INEQUALITIES ON THE BALANCE.

BY L. D. WELD.

The topic herein presented had its origin in some work preliminary to another investigation, requiring the use of a sensitive balance operated with the greatest possible degree of precision. The balance used is by Sartorius, with 18 cm. beam and sensibility of about 2.3 scale divisions per mgr., pans empty, and so constructed that the sensibility increases slightly with moderate increase of load. The writer was studying this balance with a view to getting acquainted with its peculiarities, determining its constants and learning what degree of precision to expect of it (as should always be done with a new balance about to be used in particular work), and had taken a series of consecutive zero readings by the oscillating pointer method with pans empty, when a marked progressive change in the readings attracted immediate attention and demanded explanation.

The first readings, separated by a few moments only, were as follows:

10.56	10.33
10.56	10.32
10.41	10.27
10.45	10.26
10.37	10.09

Subsequent sets of readings, in which a fair degree of constancy had been secured, gave the probable error of a single pointer reading as less than 0.03 scale division, so that the change observed must have been real and not due simply to errors of observation.

Variations of temperature were naturally looked to as the probable cause. The balance was badly located, with the right end of the case adjacent to an outside wall and the left away from it. At this particular time, the wall was cold, and the temperature of the room was rising, so that such an effect was to be expected. But balances are frequently used in just such locations, and the magnitude of the change, amounting in only a few minutes to what would be equivalent with this balance to over 0.2 mgr. placed upon the right-hand pan, was such as not to be tolerated in precise weighing. It was thought well, therefore, to look into the matter somewhat before entering upon further work.

After experimenting for a time with sensitive thermometers placed inside the case, the writer prepared a thermo-electric arrangement of ten pairs of elements, which was suspended immediately behind the beam with the two sets of junctions in juxtaposition with the two end knife-edges. This apparatus was connected with a sensitive D'Arsonval galvanometer of the wall type, which gave a deflection of twenty scale divisions per degree centigrade, so that the temperature difference between points very near the ends of the beam could be fairly estimated to about one two-hundredth of a degree. The object of this arrangement was to study the effect of known temperature inequalities in the case upon the zero readings of the balance. One set of results must suffice here. In these, the conditions were in a measure controlled by having an electric light mounted outside the case at the left end, and turning it on and off at will. The accompanying figure best illustrates the results, which are tabulated below.

Time P. M.	Galv. Read.	Pointer Read.	Remarks
4:10	2.9	10.12	Light off
4:17	15.1	10.47	Light on
4:20	16.9	10.55	Light on
4:22	17.9	10.69	Light on
4:26	11.0	10.60	Light off
4:34	7.8	10.30	Light off
4:36	6.4	9.97	Light off
4:37	15.0	9.84	Light on
4:39	16.8	10.04	Light on
4:42	18.0	10.21	Light on
4:45	19.0	10.30	Light on
4:48	19.5	10.35	Light on
4:52	20.1	10.32	Light on
4:54	20.5	10.29	Light on
4:58	20.9	10.20	Light on
5:03	11.0	9.84	Light off
5:05	8.8	9.33	Light off
5:07	7.0	9.24	Light off
5:10	6.0	9.01	Light off
5:12	5.3	8.99	Light off
5:17	4.9	8.94	Light off
5:19	4.3	8.99	Light off
5:21	4.1	9.01	Light off

An examination of these curves suggests several things. Note the remarkable promptness of the pointer reading effect when the light is turned on. The second drop in the pointer reading *precedes* the drop in temperature difference, and is gradual instead of sudden, showing that it is due partly to other causes. This does not occur in the first and shorter exposure to radiation. No doubt the other causes operating to bring down the pointer reading are the equalization of temperature in the beam by conduction and the gradual growth of air currents in the case by contact with the warm glass on the left side. The same thing is noticed in the rise of the pointer reading at the end of the series, while the temperature difference is still decreasing. It is to be noted that the whole range of temperature difference is less than one degree.

It is evident that air currents in the case, set up by difference of temperature at the two ends, have an effect opposite to that of expansion in the beam. For. the current is downward at the cooler end, bearing down on the pan; while the corresponding arm is the shorter, which tends to raise the pan. It is difficult to say how much the effect of expansion in the beam may be thus modified by the air currents; but it is likely that with broad pans the modification may be considerable, providing the air currents have had sufficient time to get fairly started.

The statement is made in some laboratory manuals that the difference in length between the two arms of a first-class balance when in adjustment will be found negligible for all but the most precise weighing, for which latter purpose the interchange of object and weights is recommended. This is perhaps quite true, providing the beam is at a uniform temperature; but the experiments herein described show how marked may be the effect of even slight temperature inequalities. Moreover, if such inequalities exist, unless they can be kept constant throughout the various operations of the double weighing, with the opening and closing of the case that are necessary in any balance not provided with special reversing apparatus, the interchange method does not remedy the difficulty.

The writer made two double weighings of the same object by the interpolation method, using the same individual weights in both cases, but under different temperature conditions. The first set was made on a warm day, the room being considerably colder than outside; while the second set was made on a cool day, the room being steam heated. The balance had not been adjusted as to arm ratio since its arrival from the makers; and the right arm was still toward the outside wall. The results were as follows:

FIRST SET.

Object on left pan ....19.23112 grams
Object on right pan ....19.23219 grams

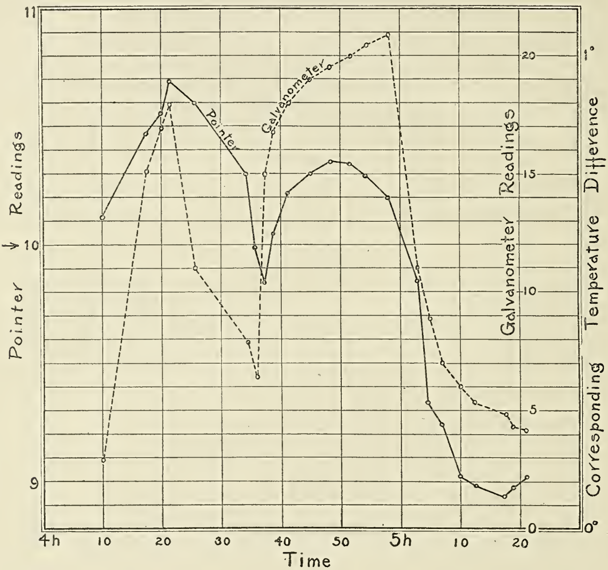
SECOND SET.

Object on left pan ....19.23148 grams
Object on right pan ....19.23213 grams

The right arm is obviously the longer in both cases. But if the mean of the first set be taken, it will be found that the residual or departure of each weighing from it is 0.00052, while for the second set the residual is only 0.00032. The explanation of this is, that in the first case the right arm was warmer than the left, thus adding to the inequality, while in the second, it was cooler, subtracting from it. The difference in temperature at the ends of the beam could not have been in either case more than one or two-tenths of a degree, as indicated by the galvanometer.

The beam of the balance here used is of phosphor-bronze, with a centigrade coefficient of expansion, according to the makers, of 0.0000181. A simple calculation, using this figure and the known constants of the balance, shows that a uniform temperature gradient of one degree from one end of the beam to the other, barring air currents, would produce an anomalous deflection of about 1.8 scale divisions, corresponding to well toward a milligram. The thermo-electric apparatus, when used under the best conditions obtainable in the winter with the balance situated as it was, though carefully screened and blanketed, showed temperature gradients of nearly one-fourth of one degree, and much greater ones when no special precautions were taken. The variations observed are therefore not at all surprising.

In conclusion, it may be suggested that sufficient care is seldom taken in conducting balance work to secure freedom from the disturbing influences of temperature gradients, direct radiation and accidental air currents. For successful work, the balance should be centrally located in a quiet, thermostatic room, on a pier if possible, and carefully screened from radiations from heating apparatus, artificial lights and sunlit windows. It is well to blanket the case, and the illumination should come from the front, not from the side. Unless such precautions are taken, it is doubtful if the great precision often claimed for weighing methods can actually be realized. Further, it will be found a source of satisfaction, to anyone endeavoring to get the best results from weighings, to install within the case, as described, a thermo-electric series of simple design, which will give warning of the presence of temperature inequalities, and thus indicate when the best conditions exist. Such a thermopile may be easily made in any laboratory shop from iron and copper wires mounted on an ebonite or wooden frame, and can be located so as to be used during weighing without being in the way.



EVAPORATION FROM FREE WATER SURFACES.

BY ARTHUR G. SMITH.

The very extensive work being done by the United States Reclamation Service in the storing and preserving of the waters of the arid and sub-arid regions of this country, has brought prominently before irrigation engineers the question of the amount of evaporation taking place at different places and under various external conditions.

Taking for example the annual evaporation from a reservoir in Arizona, as amounting to six feet, and supposing the amount of water needed for satisfactory irrigation as two feet then we see that in a reservoir like the Roosevelt reservoir with a surface of 16,000 acres area, it means that the efficiency of the reservoir is reduced by nearly 50,000 acres. A loss that is very considerable in comparison with the total capacity of the reservoir.

If we suppose the value of the irrigation to an acre of ground to be say five dollars a year, then this evaporation means a loss of a quarter of a million dollars a year to the arid region surrounding this particular reservoir.

While the amount of evaporation from the water surface is a matter of both scientific and economic importance in the arid west, it is also of considerable interest in the humid regions of the middle west.

During the summer of 1906 through the kindness of Mr. A. H. Horton, United States Hydrographic Engineer, an evaporation gaging station was established at Iowa City, the reader having charge of the work.

It is a well known fact that the evaporation consists of two steps; first the liquid must be changed to the vapor state forming a film as it were upon the water surface and then this film must be removed by the atmospheric movements in order that another dryer layer of air may take the place of this saturated film and take up the succeeding evaporation. The amount of evaporation will of course depend upon vapor pressure and this will depend upon temperature. The removal of the film of saturated air and its mixture with the upper layers of the air, depends very largely upon the wind. If we think of the wind as advancing across a considerable body of water and thus becoming more or less saturated with water vapor, the removal of the film will become less and less effective. It may then be expected that the average evaporation will not be so great from a large body of water as from a smaller area for the unit area. During the midsummer months the water surface is cooler than the air above and the tendency is for the cooled air in contact with the water surface to hang upon the surface sinking rather than rising unless the wind is sufficient to remove it. Later in the year, say from the middle of August on the water surface except in the middle of the day is warmer than the air above and the air warmed by contact with the water not only takes up the water vapor but then rises from its expansion and gives place to dryer air; thus the amount of evaporation is increased especially during the night time.

In order to measure the evaporation from the surface of streams and lakes, pans are floated in them and the evaporation from these pans is measured. In order that comparisons might be made upon the relative rates of evaporation from pans similar in every respect except that one is surrounded by land and the other by water, two pans were installed.

One was floated upon the river and the other imbedded in the ground upon the bank of the river; the pans were three feet square and eighteen inches deep, filled with water to within about one and one-half inches of the top. A sharp point set in the middle of the pan is just kept covered; the amount of evaporation being measured by the number of cups of water required at time of observation to just cover this point.

By using a rain-gage to allow for rainfall it is possible to measure with accuracy to the one-hundredth of an inch the amount of evaporation.

The surfaces of the water in the pans were adjusted morning and evening at 8 A. M. and 6 P. M.; the temperature of the water being taken both in the pan and in the river outisde. By means of a sling psychrometer the relative humidity was determined at seven o'clock both morning and evening. An estimate was also made of the maximum velocity of the wind in the course of the twenty-four hours.

The amount of data collected, to the present time, is not sufficient to warrant more than the noting of certain facts; one can hardly say conclusions, for conclusions resting on insufficient statistical evidence becomes nothing but weighted guesses. To note briefly some of the results obtained: The total amount of evaporation, from the river pan during the summer of 1906, was in excess of that from the land pan in the ratio of 100 to 90; during the six months from April 1st to October 31st, 1907, while reading were made, the evaporation from the land pan exceeded that from the river in the ratio of 100 to 92, and the month of April, 1908, just past, has shown an evaporation from the land pan one-fourth greater than from the river pan. While at first thought it might be expected that the evaporation from the land pan would be the greater, it should be borne in mind that the river pan, especially in the late summer and fall, has a temperature markedly above that of the land, and for this reason the rate tends to rise higher for the river pan at this time of the year. It is the reader's opinion that on the whole the evaporation from the river pan will be found to be above that from the land pan. This is of course for a pan upon a stream as small as the Iowa river.

The following table gives the evaporation from the two pans for the six months of 1907, named above and also April, 1908.

	Land pan	River pan	Relative amounts for night or day	
1907	Inches	Inches	Land	River
April	2.95	2.14	57%	56%
May	3.38	3.18	61	80
June	3.03	2.60	66	74
July	4.93	4.75	66	68
August	4.73	4.34	90	86
September	3.03	2.98	71	75
October	1.83	1.91	..	..
1908				
April	3.05	2.40	51	71

The following table gives the amount of precipitation for the corresponding months of the year at Iowa City.

April	3.2 inches
May	4.3 inches
June	3.0 inches
July	4.5 inches
August	3.3 inches
September	3.5 inches
October	2.4 inches

It will be seen at once that even in a humid climate like this, that the total evaporation from exposed water surfaces is quite comparable with the total precipitation, possibly as great.

The relative evaporation during the night to that of the day is perhaps larger than might be expected. This is as has already been spoken of, due in part to the higher temperature of the water during the night than of the air in contact with it. This higher temperature is much more marked for the river than the land pan.

The values found for the relative humidity at seven o'clock in the morning and evening are as follows:

Relative humidity 1907	7 A. M.	7 P. M.
April	86%	81%
May	87	79
June	88	82
July	92	88
August	91	84
September	92	87
October	94	83
1908		
April	89	79

The temperature of the water in each of the pans and of the river surface is of considerable value, giving some clue to the causes of the fluctuations in the amount of evaporation. The river temperature is also of interest as it shows the march in temperature during the summer months, in the water flowing in such a stream. The following table shows these various temperatures as well as the average temperature of the air as taken from the mean of the readings made at 7 A. M. and 7 P. M. It should be noted that this mean is some five degrees lower than the mean as computed from maxima and minima readings.

	Land-pan		River-pan		River Surface		Mean Temp.
1907	8 A. M.	6 P. M.	8 A. M.	6 P. M.	8 A. M.	6 P. M.	
April	43.0	50.0	46.3	48.5	47.3	48.2	40.1
May	54.6	61.8	57.2	59.7	57.9	59.7	54.4
June	66.7	73.0	69.0	71.4	69.0	71.8	65.0
July	74.3	81.0	75.5	78.8	77.3	78.8	72.0
August	72.0	78.5	74.3	76.5	75.1	77.0	69.0
September	64.0	68.5	68.2	69.7	69.1	70.0	61.0
October	50.0	55.5	52.7	55.5	53.5	55.7	47.0

A number of theoretical formulæ have been proposed for the computation of evaporation from freely exposed water surfaces the general form of which is the simple one given by Dalton

$$E=A\ (a-b)\ (1+ck)$$

where the arguments A,c,K are the temperature of the water surface, the dew point of the atmosphere and the movement of the wind, a and b being the dry and wet bulbs. Carpenter from Ft. Collins in 1887 proposed the following, which is of this form:

$$E,inch \div day=0.3868\ (e_W-e_D)\ (1+0.0025w),$$

where w is the wind movement per day in kilometers. The constants suggested here apply satisfactorily only to local conditions and are not general.

The author hopes in another year to offer a formula that shall be satisfactory for the Iowa river conditions but is not prepared to do so at the present time.

THE FIFTH AND SEVENTH CRANIAL NERVES IN PLETHODON GLUTINOSUS.

BY H. W. NORRIS.

Thinking that possibly some of the conditions described by Dodds (1906) in the cranial nerves of Plethodon glutinous might throw some light upon the homologies of the ramus maxillaris V in the urodele amphibians the writer was led to work out carefully the distribution of the fifth cranial nerve and its branches, together with those of the seventh nerve, in the same species.

The material, small adults 35mm. long, was fixed in Vom Rath's picro-acetic-osmic-platinic mixture, infiltrated and sectioned in celloidin, and studied entirely from cross-sections. Although the differential staining was not as thorough as the writer has usually obtained by this method with amphibian material, yet except for very minute branches its precision is reliable.

According to Dodds there spring from the gasserian ganglion of Plethodon glutinosus three nerves: rr. mandibularis, maxillaris and ophthalmicus (profundus). The rr. mandibularis and maxillaris arise together and pass out by a common foramen. I find that three nerves arise from the dorso-lateral border of the ganglion, one of which is the r. mand. Dorsal to the latter there emerge two others that evidently represent collectively the r. max. of Dodds. According to the latter the r. max. branch "passes off laterally and curves forward in two parts. One branch (infraorbital) breaks up back of the eye-ball, and the other (maxillary) passes forward a little above the maxilla." Of these two nerves that I find leaving the gasserian ganglion dorsal to the r. mand. the dorsal one is distributed to the skin dorsal and posterior to the eyeball. The more ventral passes anteriorly until it comes in contact with the posterior border of the eyeball, where it divides into about five branches, of which two are distributed to the skin dorsal and anterior to the eye, while the other branches pass ventrally and are distributed to the skin ventral and anterior to the eye and dorsal to the mouth. Dodds is doubtless correct in interpreting these two branches as the r. maxillaris V. That in many cases they arise from the ganglion as a single nerve, as described by him, is probable.

Dodds states that "the mandibular passes off laterally and soon curves ventralward to the maxilla, where it breaks up into three branches. Two of these remain in the upper jaw and pass forward well into the snout, one just external to, and the other just internal to the maxilla. * * * These two branches may possibly represent a part of the maxillary ramus. The third branch, about equal in size to the other two combined, passes ventralward into the lower jaw." Such a distribution of the branches of the mandibular ramus as described by Dodds would be very unusual. I cannot agree with him as to the facts in the case. The r. mandibularis passes ventro-laterally from the gasserian ganglion and after giving off motor branches to the temporal, pterygoid and masseter muscles and a medium sized sensory branch to the skin, divides just dorsal to the mandible into three branches. One of these passes straight ventrally through the mandible between Meckel's cartilage and the dentary bone to be distributed to the intermandibular (m. mylohyoideus anterior) muscles anterior and posterior, and to the skin of the ventral surface of the head external to these muscles. The distribution of this branch is that which usually obtains in the Urodela. Miss Bowers (1900) designates it in Spelerpes as md. internus V. A second branch runs anteriorly at the lateral border of the mandible supplying the skin of the side of the lower jaw. This branch also has nothing unusual in its distribution. It has been described in Amblystoma (Coghill, 1902), Spelerpes (Bowers) and Amphiuma (Norris, 1908) and evidently is a constant feature in urodele anatomy. Miss Bowers terms it r. md. externus V. The third branch runs anteriorly along the dorsal border of Meckel's cartilage, then gradually shifts medially and ventrally between the cartilage and the angulo-splenial bone and fuses with a branch of the r. alveolaris VII. This combined nerve of general cutaneous and communis fibers runs anteriorly, presumably to supply the teeth and lateral floor of the mouth. This third branch has no peculiarities, and its anastomosis with the alveolaris has been described in Amblystoma and Amphiuma. Miss Bowers does not describe it in Spelerpes, but my own preparations of Spelerpes show it very distinctly, and that the anastomosis with the alveolaris undoubtedly occurs. None of these three branches of the r. mandibularis remain in the upper jaw, nor can I find any branches such as Dodds describes in the upper jaw.

Coghill describes in Amblystoma an anastomosis between the motor portion of the r. mand. supplying the intermandibular muscles and the motor part of the r. jugularis VII supplying the interhyoid muscle. A similar anastomosis occurs in Plethodon.

Of the ramus ophthalmicus profundus V Dodds says: "It soon divides into two branches. One of these extends dorso-lateral and breaks up in the muscles in front of the eye." Although this is not a positive statement that this dorsal branch is motor, yet such an inference may be drawn. There are no muscles in Plethodon anterior to the eyeball unless we except the superior and inferior oblique muscles of the eyeball itself. Furthermore, this dorsal branch is exclusively general cutaneous in composition and is distributed to the upper eyelid and the skin of the dorsal side of the head mesial and anterior to the eye. Examination of the published figures of the cranial nerves of Amblystoma, Spelerpes and Amphiuma shows that similar branches are found in these forms. Dodds correctly describes the three terminal divisions of the main portion of the r. oph. prof.: a mesial, a lateral and a ventral branch, the latter anastomosing with the r. palatinus VII. The condition seems to be similar to that in Amblystoma and Spelerpes. Of the exact nature of the anastomosis with the R. pal. VII the material studied does not give exact information. Apparently it differs from that described in Amblystoma and Amphiuma.

In the material studied the lateral line system had disappeared. Hence the VII-VIII complex is much simplified over that of the larval stage. The VII-VIII nerves arise from the brain by three groups of rootlets: a dorsal communis, a middle auditory and a ventral motor group. From the common ganglion of the VII-VIII nerves an anterior auditory vestibular branch passes to the utriculus and the anterior and horizontal semicircular canals of the ear. From the posterior part of the ganglion a number of auditory branches pass to the sacculus, lagena, etc. Dodds says that a single small twig supplies this portion of the ear. From the antero-lateral portion of the ganglion the fibers of the facial nerve emerge in two parts: an anterior r. palatinus and a lateral r. hyomandibularis. The palatine branch passes anteriorly to its anastomosis with the r. ophthalmicus profundus already mentioned. A Jacobson's commissure between the IX nerve and the r. pal. VII evidently exists, but its entire course was not traced. The main portion of the facial nerve, truncus hyomandibularis, passes posteriorly, laterally and ventrally from the ganglion. It soon gives off a r. alveolaris (not noticed by Dodds) that passes antero-ventrally to supply the lateral floor of the mouth. Its anastomosis with the r. mandibularis V has been described. Near the place where the r. alveolaris leaves the hyomandibular trunk the latter receives the ramus communicans from the IX nerve. Most of the fibers of the r. communicans enter the r. alveolaris and are evidently communis.

Of the exact composition of the r. communicans no reliable information was gained, but apparently general cutaneous fibers are contained in it. The condition seems to be very much like that described by Coghill in Amblystoma. After giving off the r. alveolaris the hyomandibular trunk supplies the depressor mandibulæ, sphincter colli and interhyoideus muscles and apparently sends general cutaneous fibers to the skin overlying these muscles.

A comparison of a plotting of the fifth and seventh cranial nerves of an adult Plethodon with that of a larval Spelerpes (as given by Miss Bowers), shows that after omitting the lateral line system of the latter the resemblances are very close, so close as to make evident an almost identical arrangement in the two.

It would appear that Dodds is completely in error in supposing that there are any anomalies in the composition and distribution of the fifth cranial nerve in Plethodon glutinosus.

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THE RELATIVE FREQUENCY OF ARTERIO SCLEROSIS OF THE VARIOUS ARTERIES.

BY W. E. SANDERS.

The present paper is a preliminary report of one phase of a series of arterio sclerotic cases which the author studied during the summer of 1908 while engaged in pathological studies in Berlin and Munich.

A brief autopsy report was taken of each case, especial attention being given to the condition of the heart and kidneys.

The macroscopic appearance of the vessels were noted at the autopsy and specimens taken for further microscopic study. The vessels selected were the arch of the Aorta, the Pulmonary, the Coronaries, the Splenic, the Renals, the Internal Carotid, just below the circle of Willis, or pre fossi sylvii, and occasionally various other arteries.

The material included only selected cases from some 300 post-mortems with a view of eliminating syphilitic endo and mesarteritis and including only early cases of the so-called senile artero sclerosis, the primary object being to determine the nature and location of the initial process and if the same be of a circumscribed or diffuse character. The critical phases of the subject I shall not discuss in this paper but shall reserve it for a later contribution.

The specimens were fixed in 2 per cent Formol cut with the freezing microtome and stained with Hæmatoxoylin and Sudan iii, for degenerative changes, and Carmine and Weigert's elastic stain for the changes in the elastic elements.

The following is an epitome of twenty cases. In describing the extent of the process I have used the terms minimal, moderate and pronounced. It must be understood, however, that these terms are used only in a relative sense as the cases were most all as I have previously stated in the initial or early stage of the disease.

Case I. Male, 51. Died from carcinoma of the œsophigus.

The thoracic aorta was free, the abdominal aorta minimal sclerosis. The left coronary and splenic minimal, the right renal moderate and the left renal and the right femoral pronounced changes.

Case II. Male, 56. Died from Addison's disease.

Thoracic and abdominal pronounced, both carotids and both coronaries moderate, splenic, both renals and the coeliac axis minimal and the basalar and cerebrals free.

Case III. Male, 46. Died from purulent meningitis.

The thoracic and abdominal aorta, the subclavian, both carotids, the splenic and both renals minimal, the left coronary pronounced, the right coronary and cerebrals free.

Case IV. Male, 47. Died from a myxo sarcomatous tumor of the mediastinum.

Thoracic and abdominal aorta, splenic and left renal minimal, left and right coronary and right renal moderately effected.

Case V. Male, 76. Acute infection, likely influenza.

Thoracic and upper abdominal and right coronary moderate, descending branch of the left coronary pronouncedly, splenic, left renal and internal carotid negative, pulmonary minimal.

Case VI. Male, 72. Died from cerebral apoplexy. This case was rather advanced but was studied with a view of noting the condition of the vessels in general in relation to the apoplectic insult.

Pronounced sclerosis of the aortic arch, atheromatous ulcer of the abdominal aorta, splenic and coronaries pronounced with calcification of the latter, right renal moderate, left renal, pre fossi sylvian and pulmonary minimal. The subclavial and common carotid pronounced, the basalar and vertebral were negative notwithstanding the cerebral hemorrage.

Case VII. Male, 39. Died from pernicious anæmia.

The aortic bulb at the origin of the left coronary as well as the latter itself show minimal localized sclerotic patches, the left common carotid moderate, coeliac, both renals and the splenic minimal. The right coronary and prefossi sylvii were not studied.

Case VIII. Male, 47. This was a medico legal case, the man dying suddenly after falling on the sidewalk. Examination revealed pronounced sclerosis and some atheroma of the aortic arch and pronounced sclerotic stenosis of the origin of the left cornary. The right coronary was minimally effected. The other vessels were free.

The diagnosis of angina pectoris was established.

Case IX. Male, 68. Died from carcinoma of the ampulla of the rectum. The aortic arch showed minimal sclerosis, the abdominal aorta moderate sclerosis with atheromitous ulcers about the original of the renals. The cerebral vessels were not examined but the other vessels revealed no macroscopic changes.

Case X. Male, 34. Died from peritonitis, caused from a perforating carcinoma of the stomach.

The arch of the aorta showed minimal circumscribed slightly elevated yellowish sclerotic patches. The other vessels were free.

Case XI. Male, 40. Died from typhoid fever.

The aorta and the pulmonalis showed moderate circumscribed slightly elevated yellowish sclerotic patches. The other vessels are not diseased. This case is of interest because of the infection which existed, some authorities claiming infections, particularly typhoid, as an important etiological factor in arterio sclerosis.

Case XII. Male, 33. Died from heart disease. This case is of special interest because the sclerosis was practically limited to the pulmonary arteries while the systemic vessels were free. I have reported the case elsewhere. (Arch. of Internal Med., April 15, 1909.)

The aortic arch showed minimal sclerosis but the pulmunary, especially the medium and smaller branches revealed a pronounced diffuse sclerotic thickening limited to the intima.

Case XIII. Male, about 50. Died from cerebral hemorrage.

The coronaries, the basilar, the pre fossi sylvii and the cerebral all pronouncedly affected. The aorta, the renals and the splenic only minimal changes. This man also had a gastric ulcer which very possibly was induced by sclerosis of the gastric vessels.

Case XIV. Male, 40. Died from tubercular meningitis and pulmonary tuberculosis.

The aorta from the arch to the iliacs showed moderate sclerotic patches. The pulmonary minimal, also the coronaries, the inferior thyroid, the pre fossi sylvii and the right common iliac moderately affected.

Case XV. Male, 31. Diagnosis cardiac insufficiency. Right side pleurisy. Aortic arch pronounced plate like sclerotic elevations. Thoracic aorta minimal pessary like elevations around the orifices of some of the intercostals. The coronaries, the renals were very slightly affected, while the splenic and pre fossi sylvii were negative.

Case XVI. Male, 54. Died from heart disease, odœma of the extremities marked.

Aorta and both renals moderate, coronaries minimally affected. This may have been syphilitic.

Case XVII. Male, 62. Died of sepsis from a carbuncle. Had also chronic interstitial nephritis.

Aorta pronouncedly sclerotic with atheromatous degeneration in the abdominal portion. Coronaries, splenic and renals moderately affected, arteria pre fossi sylvii very slightly.

Case XVIII. Female, 48. Died from heart disease, old mitral stenosis and acute endocarditis.

Aorta minimally, stem of pulmonary moderately, while the medial and the smaller sized pulmonary vessels are pronouncedly sclerotic. The splenic, renals and vertebral show only minimal sclerosis.

Case XIX. Female, 60. Died from some acute infection.

Pronounced sclerosis with some atheroma of the aorta, both coronaries and both renals moderately and the splenic and pre fossi sylvii only slightly affected.

Case XX. Male, 40. Died from carcinoma of the pancreas.

The aortis arch, moderate circumscript patches near the origin of the carotids and coronaries. Abdominal portion atheromatous changes some in the ulcerative stage, the coronaries themselves only minimal sclerosis. Renals coeliac and pulmonalis free.

These twenty cases showed four between 30 and 40, seven between 40 and 50, four between 50 and 60, three between 60 and 70, and two between 70 and 80. The youngest was 31 and the oldest 76.

Chart I. * = not studied; o = negative; i, ii, iii = minimal, moderate and pronounced sclerosis.

Of the twenty cases studied, nineteen or 95 per cent revealed sclerosis of the aortic arch; fourteen or 70 per cent of the thoracic; fifteen or 75 per cent of the abdominal; fifteen or 75 per cent of the left coronary; twelve of the eighteen right coronaries, or 60 per cent; thirteen of the left renals, or 65 per cent; fifteen or 75 per cent of the right renals; twelve out of nineteen, or 57 per cent, of the splenics; five of the thirteen, or 37 per cent, of the pre fossi sylvii. In general the degree of the process is in accord with its frequency.

Without entering into detail I may state that the result of my study has demonstrated conclusively that so far as histological evidence is concerned the process is essentially limited to the intima being of the hyperplastic connective tissue type. The character of the rather superficial circumscribed yellowish elevations so commonly observed in infectious cases, correspond very well with the changes produced experimentally by treating animals with such substances as adrenalin, nicotine, bacteria and their toxins, et cetera, and I am by no means convinced that they bear any relationship to the type of sclerosis here discussed.

The degenerative changes which occur in advanced cases are invariably of a secondary character and almost always begin in the deeper layer of the intima. One of the early changes observed in the smaller vessels is a fission or lamellation of the elastica interna, the interstices becoming filled with connective tissue cells.

THE SUMMER-RESIDENT BIRDS OF POLK COUNTY, IOWA.—A GUIDE TO LOCAL STUDY.

BY LESTER P. FAGEN.

This paper consists of notes on the more common summer-resident birds of Polk county, Iowa. Its purpose is not to give an exhaustive treatment of the subject, but merely to include those birds which the true, faithful student can expect to find nesting in this county every summer.

This is not in any way a key to the identification of the birds when found. There are many books giving reliable color keys for that purpose, perhaps the best one of which is Chapman's "Birds of Eastern North America."

The true purpose of the paper is two-fold. First, to give the reader a glimpse of the possibilities of profitable, extensive study which may be prosecuted by one desiring to become acquainted with the birds of this county.

Second, to furnish a guide to the local study of our Polk county summer birds. I have selected one hundred birds, all but a very few of which are now common, during the nesting season, in this section of the state. I have drawn upon my twelve or fourteen years of almost continual observation to localize for this county what is given in a general way by most writers on the subject of birds.

Polk county, Iowa, is an exceptionally well favored section for the study of birds, for in it we find everything of environment from the open stretches of prairie to the deep, quiet woods, from the high, dry uplands to the lowland, riverbottom marshes, everything from the flat, level prairie to the rugged, wooded hills; and streams of nearly all sizes with occasionally large ponds and small lakes. Each locality attracts its different types of birds, and until very recently Polk county had almost anything in the environment asked for except mountains and salt water. The past five years have made some differences, however, which have changed somewhat the personnel of our feathered citizenship, for the tiling out of our bigger marshes, the cutting down and settling up of our heavier wooded tracts have wrought changes which make it more difficult to find the birds whose haunts are the deep woods or the big swamps. The unrestrained killing instinct of man and the barbarous taste of women have also caused some of our more common birds to become little more than memories. Some of these birds once common here but for one reason or another not so any longer, I have included in this paper, stating in each case the cause of its disappearance.

This work contains then all of our common summer-residents with the local hints as to where they may be found by one wishing to use this paper as a local guide. I feel sure that it will prove in all respects reliable and trustworthy for this locality.

A word of caution, however, will not be out of place at this time for the one who is to begin this personal study of birds. To such a one let me say,—do not expect to find all of these birds in one week or even in one season. When hunting birds, do not wear flashy, startling colored clothes. Do not approach the bird you are seeking to identify in a direct line nor in a stealthy manner.

After identifying a bird, do not rush off at once to find another but watch the one that you have found and become acquainted with him,—his manner of feeding, his call notes and songs, his peculiarity of flight, and if possible, his nesting place.

Learn not to be discouraged or surprised if, some days, you arrive in a locality that should be full of birds and fail to find any. That is one of the most valuable assets in your search for birds, though by no means necessary, is a good field glass or a pair of opera-glasses.

With this much for suggestions and instructions, I shall now proceed with the individual consideration of the birds, taking them up in their order of families.

ORDER PASSERES: PERCHING BIRDS.

American Robin. By far the best known of our native birds, the robin heads our list. From early March until the snow begins to fly the following winter, his cheery song in its simple melody resounds throughout city streets and around our farmhouses and orchards. His nest, a course structure of hay and twigs plastered outside and in with mud and lined with dried grass, is easily found and recognized. In it are laid four to six eggs of a peculiar shade of greenish blue.

The Wood Thrush. In some localities, this second of the silver tongued family is known almost as well as the robin, but not so in Polk county. From early May till late in August, in the heavier wooded hills, his voice may be frequently heard in its ringing melody. Seen at close range, his beauty is a match for his rolling, vibrating song. His nest and eggs are much like that of his cousin, the robin. The wood thrush stays here until in October, when he leaves to return about the first of May.

Wilson's Thrush, Veery. The veery is the most slender and graceful of the thrushes. Its first arrival in early May will be the best time to see it, for when it retreats into the woods to build its nest, all disappears except the voice, that ringing "echo-song" that causes one to listen in glad bewilderment, then search, ofttimes in vain, to find the singer. His nest is like the wood thrush's, but it lacks the mud. Its eggs, its haunts and winter home are so like those of the wood thrush that a separate description is not needed.

Blue Bird. The baby blue bird first sees the light in the inside of an abandoned woodpecker's hole, a bird house, or decayed knot hole, and learns to fly within a few short weeks. Late in October he leaves the state of his birth to take up winter quarters in the Gulf states and Cuba, only to return again in early March to vie with the robin for first honors in reporting coming spring. His song is mellow and assuring. Heard at a distance it has a purling quality and through it all runs a note of sadness that blends in rare harmony with the cheery, rolling notes of the robin and the wood thrush.

Chickadee. This jolly sociable little fellow is a yearly resident with us and may be found wherever there are trees or bushes. He builds a tiny nest of feathers and down in a hole in a stump or tree a short distance from the ground but well concealed. His song has a care free merry ring to it which goes well with the character of the singer.

White-Breasted Nut-Hatch. Though excelled as contortionists by the parrots, the nut-hatches stand in a class by themselves,—our recognized bird acrobats, running head downward down a tree on the under side of a limb, using only their feet as means of support and never their tails as do the woodpeckers and creepers. This white-breasted cousin of the chickadee reminds one often of our little black-capped friend, staying with us all the year and showing many of the jolly, sociable characteristics of his irrepressible cousin. His nest is much like that of the chickadee except that the hole which he uses is excavated by the nut-hatch himself, and is not a natural cavity or an old excavation. In winter the nut-hatches are often found with flocks of titmice and kinglets, and are of our most beneficial birds, destroying thousands of scale insects and eggs of larger ones.

Red-Breasted Nut-Hatch. What has been said of the preceding species can be said of this except that as a rule, in this part of Iowa, the red-breasted one is much shyer and more retiring than the white-breasted. The red-breasted species is really rather rare in Polk county the past few years, though in some parts of the state it is more frequently found than the white-breasted.

Cat Bird. The cat-bird, one of the tamest of our native birds, is a true mocker, but he also has a song of his own that is full of rolling melody, only slightly inferior to that of the brown thrasher. From early May until October or November he may be found in and about the gardens and orchards, stealing fruit sometimes, but always eating insects. His nest is built in a bush or small tree, and looks much like the thrush's but lacks the mud. The cat-bird winters in the southern states and Central America.

Brown Thrasher. From the time of his arrival about the last week of April till the last week of June, the thrasher is the most enthusiastic songster we have. For the first week or two, there is a continuous flow of almost uninterrupted song. Then begins the nesting period. The music does not stop, however, but continues at intervals every day until the last of June.

Though not quite so common or sociable as the cat-bird, it is a well known bird in the spring, seen frequently at midday on the topmost twig of a tall tree, pouring out his soul to the great world about. Its habits, though confined more to the light woods, are very much like the cat-bird's. Its stay here ends early in October, when it leaves for winter quarters in the southern states.

House Wren. These busy little bodies, the children's favorites, arrive usually about April 15th and stay until the first week in October, during which time three nests are built and three broods raised. The nest is built in corners about houses, barns and outbuildings, in old shoes, mittens, cans, boxes, and indeed anything that can be made cozy when nearly filled with sticks and straw.

The wren, being so small, hardly suggests its relationship to the cat-bird and brown thrasher except by his busy habits and the joyous manner of his singing all the day through.

The house wren's winters are spent in the southern states and Mexico.

Long-Billed Marsh Wren. A bird of moist meadows and reedy swamps, we find this fellow nearly as jolly and fearless as the house wren itself. He builds his nest and lives in places not easily accessible by man.

One nest is built for the rearing of the brood, and while the eggs are being laid and hatched, the male builds from four to seven dummy nests near the real one in more conspicuous places to delude the molester. Their stay here is from early May until September.

Short-billed Marsh Wren. The short-billed marsh wren is much rarer than the long-billed species, erratic in its habits, some years being found in several marshes about Des Moines, and other years in none of them. Their habits and all are identical with the long-billed except that they are shyer.

Black and White Warbler. This alert little fellow is only spasmodically common in Polk county, some years being very rare indeed. His arrival from Central America is about May first and his departure for the south again is about September first. His habits are so like those of the downy woodpecker, as he rambles around over the trunks of the trees in search of larvæ, that you may easily mistake him for the downy. His nest is hidden very adroitly in a stump or on the ground, and is one of the most difficult to find.

Yellow Warbler. From their winter home in northern South America, these little fellows arrive about May first to stay until September. They are very sociable and confiding, feeling as much at home in the trees by the house as in seclusion.

This is the little warbler who always baffles the lazy cowbird, when her nest is victimized, by building a second story over the unwelcome egg, leaving it in the one below.

The yellow warblers, like all other warblers, feed entirely on insects, and are of invaluable aid to the farmer and fruit raiser.

Chestnut-Sided Warbler. A shy little bird, of a retiring disposition, the chestnut-sided warbler is not well known in Iowa. It is not found here in great numbers, but in the spring may be found often in company with the redstarts feeding industriously on the insects in the orchards and gardens. When the nesting season arrives, they retire to the seclusion of the woods and are very seldom seen or heard. From May to September is their season in central Iowa.

Prairie Warbler. The prairie warbler is probably the smallest warbler that nests here, and has a quaint and curious song, for which it is most noted. Found usually in shrub dotted pastures or brushy light woods it builds an elaborate and beautiful nest in a small tree or low bush.

Ovenbird: Golden Crowned Thrush. To come to know the Ovenbird is one of the greatest feats of the nature student, for while not rare in Polk county it is one of the most shy birds we have. A bird of the deep quiet woods, his wild defiant call of "Teacher, teacher, teacher," is in keeping with his life of untamed freedom. His love song, melodious beyond description, is seldom heard by human ear, while his nest, that little hut of dead leaves and grasses with the door at the side, though widely famed, is seldom found. His season with us is from May to October.

Maryland Yellow-Throat. One of the merriest, most bewitching of our ground warblers, the Maryland yellow-throat can be found in old brushy pastures or near willow-edged swamps at nearly any time during the summer.

From his arrival in May until his departure for the Gulf states, in September, his song may be heard and his happy, roguish face seen by the earnest seeker. His nest is large and deep, sometimes partly roofed over, made of broad grasses and put either on the ground or in a bushy tangle.

Yellow-Breasted Chat. The most distracting, uncertain bird in the whole tribe, the yellow-breasted chat seems to take almost fiendish delight in the bewilderment caused bird lovers by his mocking, ventriloquous voice. The chat can imitate almost any bird as well as man's whistle and voice. With us from May first to September first.

The chat may be found usually along country roads, in small groves and about gardens and orchards. The nest is built of bark and twigs, lined with soft grasses and placed in briary, inaccessible bushes near the ground.

American Redstart. This little, self-important warbler reminds one of a miniature bantam rooster when seen strutting about on the ground the first day of his arrival from the south in early May.

When the nesting time comes, he retires to the quiet of the woods. Kirkwood Glen, a few years ago, was a favorite resort for the redstart, but now we must go farther, to Walnut Creek or Four Mile Creek or the wooded tracts off of Beaver Ave. and North Thirtieth Street. The nest is a carefully made structure of moss fibres and horsehair, set in a forked branch about twenty feet from the ground.

Like many other warblers, the redstart leaves for Mexico and South America in September.

Red-Eyed Vireo. This bird that always builds into its nest some cobwebs, and usually some scraps of hornets' nests, is one whose song is seldom noticed until late in May, but from then on through July it is a constant singer. In our groves and lightly wooded tracts, the red-eyed vireos nest in comparative abundance throughout Polk county. The nest is one of the most beautiful and perfect we have. A cup-like, pensile nest in a slender fork of maple, oak or apple tree about eight or nine feet from the ground, it is a most remarkable piece of workmanship, composed of fibers, string, cobwebs, scraps of paper and bits of hornets' nests, all woven in to form a firm, durable structure of great beauty and daintiness.

White-Eyed Vireo. The general habits of the white-eyed vireo resemble those of the red-eyed species except that it is less common, comes later in April or early May, and builds its nest in lower bushes or vines. It frequents the gardens and orchards more than the red-eyed, and is bolder, being quite a scold at times when disturbed.

Warbling Vireo. The warbling vireo resembles very closely the red-eyed in all its habits. Its nest, however, is usually placed at a height of twenty or thirty feet and contains some moss as a rule. Its song is much more beautiful than the red-eyed, though even he has much of sweetness in his simple melody.

Loggerhead Shrike: Butcher-Bird. The shrike, known among the farmers as mouse-bird and among the boys as butcher-bird, is one of the first to arrive from the south and one of the last to leave. Arriving here the last of February or the first of March, its nest is often built and eggs laid before March 25th, while May Day has found the second nest built and eggs incubating. Two different years have I found snow on the ground when the young birds of the first brood were learning to fly.

The shrike's food consists largely of beetles, grasshoppers, mice and small birds. In localities where English sparrows are very abundant, they furnish most of the shrike's bill of fare, though I have rarely found them killing our native birds. Their habit of hanging the mice and birds killed on thorns has given rise to the name of butcher-bird.

The shrike may be found along the roads near pastures where Hawthorn or crab apple trees are found or where there is an osage orange hedge. His nest is built in such a hedge or in a thorn bush or tree. It is a large, bulky, warm structure resembling somewhat a large king-bird's nest.

Cedar Waxwing. Majestic, stately looking bird of exquisite coloring, the cedar waxwing is quite rare in Polk county during the breeding season, though abundant in the spring and fall and throughout the winter, seen in flocks of from ten to thirty quite frequently, generally in the light woods or orchards.

Its food consists of seeds and insects, with occasionally some fruit when it is convenient. The waxwing's nest is a deep structure of sticks and fibers, lined with grass and feathers, and located in the crotch of an apple tree or cedar bush a few feet from the ground.

Purple Martin. The most common of the swallows in and about Des Moines, the purple martin may be seen on the telephone and telegraph wires throughout the residence districts of our city and along most of the roads leading to it.

Their season here is from the middle of April to the first of September. Their nests are built in boxes, corners of buildings and hollow trees, and consist of a little heap of leaves and a few straws.

Barn Swallow. Next in order comes the barn swallow, known by his long, forked tail, and building his nest of mud and straw on or against the rafters of the barn or shed within easy access of the willful pilferer. His stay with us is about the same as that of the purple Martin. The diet of all the swallows is chiefly insects, caught on the wing.

Tree Swallow. This white-bellied swallow is found in some places in Polk county in rather large numbers, especially during the times of gathering before the fall migration. Their general habits correspond very closely with those of the purple martin, both in the time of arrival and departure and their nesting habits.

Bank Swallow. Arriving in May and leaving again in late August, the bank swallow makes the shortest stay of all our swallows. He is the smallest of our swallows and builds a nest in a tunnel excavated by himself in a clay bank along a river or railroad cut. This tunnel is lined with grass and feathers, making a soft, warm nest. Other habits the same as the other swallows.

Cliff Swallow: Eaves Swallow. This last of the swallows to be considered is, to some of our farmer boys, the best known of them all, for in some localities beneath the eaves of every barn are found long rows of these peculiar, gourd-shaped nests of mud, with the opening through the neck, and lined with feathers and straw. Often they are placed so close together that a single mud wall forms the dividing partition. Where there are no desirable buildings upon which to build the nests, they are built under shelving cliffs.

The barn swallow is typical of this swallow in other respects.

Scarlet Tanager. Once one of our most common and familiar birds, the scarlet tanager is our best local example of the unspeakably pathetic effect of the uncurbed exercise of a semi-savage taste. Together with all of our brilliantly plumaged birds, the scarlet tanager has been nearly persecuted out of existence, and had not prohibitory laws been passed, the present would have witnessed the list now containing the American bison, the woodcock and the passenger pigeon swelled by another once common Iowa resident. Five years ago it was an exceedingly rare bird in Polk county, but it is now on the increase, though its confidence in human kind has not returned. We must now look for it in our deep, secluded woods, though occasionally a pair is found in the more open woods and groves.

The tanager's stay with us is short, being from about May 15th until August 20th. The nest he builds is a rather flat, irregular nest of sticks and root fibers, lined with finer material of the same kind and placed on a high, horizontal branch of a white or bur oak tree.

English Sparrow. Words strong enough cannot be found to adequately express the denunciation which the bird lover feels toward this feathered pest that is overrunning our land, destroying our native birds, our grain and our buildings, and scattering weeds and vermin wherever it goes. We all know the habits of this unmitigated pest too well to need description. Let us encourage and aid in the destruction of the English sparrow wherever possible and thereby do what we can to check their increase and protect our native birds.

Vesper Sparrow. We turn now to the well known twilight singer of the road sides and the fields.

The vesper sparrow arrives here from the southern states in April and from then on until October you may hear his sweet, clear song from late afternoon until night. His nest is built in a deep depression in the ground and lined with a thick layer of soft grasses neatly woven together. These sparrows are mostly seed eaters, though during the summer, insects and berries also furnish part of their feed.

Chipping Sparrow. As the vesper sparrow closes the evening chorus of the birds, so the chipping sparrow leads out in the morning melody. This little fellow is perhaps the most common of our native sparrows in Polk county, and being of a sociable turn of mind, is found in almost every locality where the English sparrow is not in too complete possession.

Their nests are built of fine grasses lined with horse hair and placed in bushes or trees all the way from the ground up to fifty feet.

Song Sparrow. The song sparrow is the most constant singer among our Iowa birds. Arriving here in early March, his song does not cease until he leaves in November, though it changes quality and tune several times.

The singer may be found in the open fields, the shrub-dotted pastures, the light groves, the gardens and the orchards, and even in the light woods I have at times come upon him. The nest is built on the ground or in a low bush or clump of weeds, not well hidden as a rule.

Swamp Song Sparrow. Not such a singer as his cousin of the upland pastures, and much rarer in Polk county, the swamp song sparrow is, nevertheless, a splendid vocalist and a common summer resident in nearly all the swamps along our rivers and the ponds northwest of Des Moines. They are shy birds and build their nests in the reeds and swamp grass or in small bushes in the swamps and may be found here nearly any time from the first of April until their departure for the southern states in late October.

Field Sparrow. Another half shy, half bold little songster of the fields and meadows. The field sparrow is quite common in the meadows about Des Moines, though heard much oftener than seen. Its season with us is almost identical with that of the song sparrow, as are also its nesting habits.

American Goldfinch: Wild Canary. This cheery, genuine whole-souled little beauty, with his confiding, happy manner and wild carefree, canary-like song, has an individuality all his own.

The American goldfinch arrives here late in April, but he stays until late in December before leaving again.

Their nests are of the softest possible material, often composed entirely of plant and thistle down. The nest is round and very neat and compact, placed in a bush or a tree where it is well protected by surrounding branches or thorns, and where it is pretty well hidden.

Cardinal. The American red bird or cardinal is entered in this treatise of Polk county birds, not because it is a common resident here, but because in the past few years it has become quite a common bird in the southeastern part of Iowa, and I have the boldness to prophesy that in the next ten years it will be frequently found nesting in Polk county. Already I have twice seen the cardinal in our county as a wild bird, and with continued protection I look for it to become one of our much loved Iowa birds.

Towhee, Chewink or Ground Robin. The towhee, one of the common summer residents of Polk county, usually arrives about the middle of April. It is one of our shy birds, to be found in the quiet wooded strips along the smaller creeks or near brush thickets, nesting on the ground in a clump of underbrush where the nest is well concealed. The towhee is a very restless bird and is to be frequently found upon the ground scratching among the dead leaves for insects and seeds which it eats with equal relish. The male's song is typical of the bird,—a wild, defiant, startling series of notes heard only during the nesting season. He leaves for the south again about the middle of October.

Rose-Breasted Grosbeak. Naturally a bird of the open woodland, the rose-breasted grosbeak has easily adapted itself to life in the residence district of our city where the trees are of sufficient size.

Its season with us is from about the first of May to the middle of September. It builds a neat, circular nest of fibers and grass, lined with finer grass and placed in a low tree or in a large thornbrush. Its food consists of beetles, flies, larvæ, seeds and the buds of various trees.

Indigo Bunting. This shy little friend of brilliant hue is fast becoming one of our rare birds in Polk county. Naturally a bird of the quiet, secluded woodland districts, the rapid destruction of our woods and the building of houses in those that are left, have driven this timid little fellow to other haunts. However, in the timber uplands along Beaver creek and Four Mile creek, they are still to be found in some abundance, while in many other smaller wooded tracts they are to be met with occasionally. The indigo bunting is here from the middle of May to the middle of September. Its nest is a rude, bulky structure of sticks and leaves, built in a low bush near the edge of a thicket or occasionally in a small, bushy tree.

Bobolink. I include the bobolink in this work on Polk county birds for a variety of reasons. First, because I have found the bobolink nesting in Polk county a few times. Secondly, because of all birds famed for its song in our middle and northern states, none is more widely known or loudly praised than the bobolink. Thirdly, because several times in the last five years our Des Moines papers have contained articles on the birds found in the vicinity of Des Moines, in which the bobolink was given a foremost place and reported to be a common bird in this locality. Almost the reverse is true. The bobolink is in reality one of the rare birds in Polk county and will be seldom met with here, though in some parts of Iowa they are found in large numbers.

Red-winged Blackbird. One of the very familiar birds of our lowland meadows and marshes and along roadsides is the red-winged blackbird. From the time of its arrival early in March until it leaves in October, it proves itself very valuable to the farmer by destroying insects and cutworms in great numbers. Its nest is usually built in the reeds or marsh grass in the edge of a swamp, though I have found them a few times in pine and evergreen trees some distance from any marsh. The nest is a bulky pocket of rush blades and grass, often easily seen but very hard to get to. The red-wing is probably the most common of our blackbirds in Polk county.

Bronzed Grackle. The bronzed grackle is in habits so closely the same as the red-winged that no separate description is necessary. They are nearly as common in Polk county as the red-winged species.

Rusty Blackbird. These rusty, black fellows are not found in such large numbers in Polk county as the other two kinds just described and yet in the more secluded swamps they are found very frequently.

The rusty blackbirds do not migrate in flocks as do the red-wings, but in pairs. Except for that, the description for the red-wings fits this species too.

Yellow-headed Blackbird. Some years not found in Polk county at all and other years seen in good sized colonies, the yellow-headed blackbird presents the most surprising sight of his tribe when seen.

The yellow-headed blackbirds seem to be diminishing the past few years with the draining of our bigger swamps, and they are probably destined to become a thing of the past in Polk county, at least.

When met with, their habits are not essentially different from those of the red-winged.

Meadow Lark. Not a lark at all, but a first cousin to the blackbirds and the bobolink. The meadow lark is common in nearly every meadow in Polk county, and within the past few years seems to be growing more plentiful rather than less so. The meadow larks arrive here about the middle of March and stay until about November 1st. Their nesting habits are almost identical with those of the bobolink except that the nest is more often protected by a tuft of grass acting as a covering.

Orchard Oriole. Another relative of the blackbird, the orchard oriole is less common here than the Baltimore oriole. It is very largely a bird of the orchards, building its little cup-shaped nest of green or dried grasses nearly always in a fruit tree in some old orchard in a quiet, secluded place, for the orchard oriole is a very shy bird.

Its season with us is from May first until September. The orchard oriole is becoming more rare in the near vicinity of Des Moines, though nearly all the older orchards a few miles away will have one or more pairs each summer.

Baltimore Oriole. The Baltimore oriole arrives here from Mexico about the first of May and from then on until the last week of September may be found anywhere in the residence districts of our city and nearly everywhere in the woods where there are large, spreading trees.

Their nests are beautiul, pensile pockets, smallest at the top, and suspended from the end of long, swaying branches, from fifteen to seventy feet from the ground. The nests found near the city are made of strings, milkweed, flax, bits of cloth, rope, etc., woven compactly together. I have one nest, however, which I found in the deeper woods northwest of Des Moines which contains almost nothing but plant fibers, grasses and strips of bark; a typical nest of the Baltimore oriole before settling up of our wooded district and the consequent abundance of more easily utilized material.

Blue Jay. The blue jay, well known for his brilliant plumage, saucy airs, and harsh call notes, is one of the most dreaded foes of the song birds. Throughout the spring and summer months, these feathered bandits live largely on the eggs and young of our most useful song birds. The fear and hatred felt by our songbirds toward these daring robbers is well illustrated by the fury with which they attack the intruders whenever found near the songbirds' nest.

The blue jay is a yearly resident here and builds a bulky nest of sticks, rags, paper and leaves, in a crotch from ten to fifty feet from the ground in almost any kind of a tree.

Crow. The crow, another hated robber, not beautiful like his blue coated cousin but much more discreet and wary, is in other respects just a blue jay "built large," with a correspondingly larger capacity for the eggs and young of our feathered friends. Both of these birds are worthy of destruction, doing more harm than good and forwarding the feared extermination of some of our rare song-birds.

The habits of the crow are almost identical with the blue jay and therefore do not need a separate description. The nest is about three times as large and placed always about thirty to sixty feet from the ground, in the deeper wooded districts.

ORDER PASSERES: PERCHING BIRDS.

Sub-order Clamatores: Songless Perching Birds.

Kingbird. The kingbird has been well named, as all who are in any degree acquainted with this dauntless fighter will heartily agree. He is a born fighter and wages unrelenting war upon all crows and hawks that come within his range of vision. His food consists of insects which are caught on the wing, for the kingbird is a true fly-catcher.

From his arrival with us in early May until his departure in October, he is living on injurious insects and keeping them in check.

He is a sociable bird and can be found many times nesting in the residence districts of our city, though most commonly seen on the outskirts of our city and in the light timberland of the country near open fields and pastures.

The kingbird's nest is a rather large, bulky, deeply cupped structure composed of sticks, bark and grasses, lined with grass and matted fibers. It is generally placed in a conspicuous place in a crotch or on a horizontal branch in an orchard or thin woods.

Great Crested Flycatcher. This largest, most magnificent of our fly-catchers, the great crested, has several characteristics all its own. Being a bird of the deep, quiet woods, it is now becoming much less common in Polk county than a few years ago, though still to be found in several localities in some abundance.

Its call is a harsh, wild, weird call, suggestive of the bird and its habits.

Its nest and eggs are also of a peculiar type, for this is the bird that nearly always lines his nest hollow with a cast-off snake skin. The nest itself is usually placed in a hollow tree or in an abandoned woodpecker's hole. The eggs are striped with *longitudinal* markings *only*, of a rich purple, chestnut and chocolate brown. No other American bird lays eggs of this peculiar type.

Their season with us is from May until early October.

Phoebe. This cheery little flycatcher, the first to come and the last to leave of its tribe, is well known to all those living in the outskirts of our city or on the farms throughout the country.

The phoebe is a favorite because of its confiding sociability and cheerful habits. From its arrival early in April until its departure late in October, it is constantly to be seen and heard as it flits about catching food or building its spongy nest of mud, moss and grass. These nests are bracketed on rocks near running water in the woods, or on rafters or supporting beams of barns, bridges, porches and other buildings. They frequently harbor bird lice in large numbers and are therefore very objectionable about a house.

Wood Pewee. Though not a songbird, the wood pewee has a plaintive little strain truly musical.

The wood pewee is a very common resident here from May until October and can be found in nearly every strip of woods within the county.

Its nest is a flat, lichen covered, mossy home, saddled to a woodland limb slightly softened by decay and growing moss, on which the little nest seems but a knot.

Least Flycatcher. This smallest of its tribe is not found in Polk county in very great abundance. His season and habits correspond with the other fly-catchers except that his nest is built in an upright crotch of bush or tree and is composed mostly of plant fibers, weeds and a lining of down or horsehair.

This little fellow is usually to be found in orchards during May and September when he can be most easily found and recognized.

ORDER MACROCHIRES: SWIFTS, WHIP-POOR-WILLS, ETC.

Whip-poor-will. A strange, weird bird of the night, the whip-poor-will is much less common in this vicinity than its close relative, the nighthawk.

The whip-poor-will arrives here late in April and leaves about the first of October. Its food consists of night flying insects and moths, which it catches on the wing.

The whip-poor-will builds no nest but lays its eggs in a mossy hollow on the ground, usually a good distance from any large number of houses, though often near farm building in secluded nooks.

Nighthawk. In all its habits, the nighthawk is so like the whip-poor-will as to need almost no further description. It is a very common resident of Polk county and may often be seen flying about in the evening even far down into the city. Its harsh cry is readily recognized and never to be confused with the distinct cry of the whip-poor-will.

The nighthawk has been known often to lay its eggs on the flat roofs of buildings in the city, and though I have never known of that occurring in Des Moines, it is by no means improbable.

Chimney Swift. Another bird gaining its food while on the wing, yet neither a fly-catcher nor a swallow nor a close relative of the whip-poor-will, the chimney swift is also one of our feathered wonders.

He flies and catches his food equally well by night or day, and his loud twitter can be heard nearly any time during the summer.

The chimney swift is never seen to perch like other birds, or indeed to alight anywhere except within chimneys or hollow trees. Its claws and tail feathers (the shaft of which extends three-fourths of an inch beyond the vanes) are nearly as sharp as needles and make it easy for them to bracket themselves within the hard brick chimneys.

Their nests are open, lattice-work baskets made of small twigs broken from trees as the birds fly by and glued together and to the chimney (or hollow tree, as is the case in wild regions) by a glue secreted as saliva by the birds themselves.

The season of the chimney swift with us is from late April until well into October.

Ruby-throated Humming Bird. The only humming bird commonly found in Iowa and the only one that I have ever found in Polk county is the well known little ruby-throated species. They are not very common here, though by no means rare.

They are the smallest of our birds and build their tiny nests usually on a horizontal branch where it resembles a tiny knot. The nest is made of fern wool, plant down, etc., and covered with lichens or chips of bark. The nest disappears soon after the young birds have left it because of its minute size and the destructiveness of the weather.

The humming bird is with us from about the second week in May until some time in October.

ORDER PICI: WOODPECKERS, ETC.

Hairy Woodpecker. The least common of the five woodpeckers which I shall speak of here, the hairy woodpecker is found in the light woods along the rivers and among the wooded hills throughout the county.

He is a dashing, active fellow, a little larger than the red-head and hence easily recognized. He is a yearly resident here most often seen in the fall when the young ones are numerous. This woodpecker, as is the case with the others, drills its nest cavity out in a tree or post from eight to thirty-five feet from the ground.

Downy Woodpecker. Just a smaller edition of the hairy, in color and habits, the downy woodpecker is much more common in Polk county as well as being more trustful of the human family. This little fellow may often be seen at all times of year persistently searching the trunks of trees for insects and their larvæ and pupæ.

Yellow-bellied Sapsucker. The sapsucker is a common summer resident, arriving here in March and departing in November, and is the one destructive member of the woodpecker tribe. His pernicious habit of drilling rows of holes into our trees, sucking the sap and eating the cambrian layer of bark, has been the cause of the death of many of our fruit trees, and has brought a hearty hatred for the sapsucker from most of our horticulturists.

Red-headed Woodpecker. The red-headed woodpecker is well known wherever there is a suitable place for nesing. I am sorry to state, however, that this bird is becoming less common than he was a few years ago, due, I think, to the slaughter practiced by the thoughtless boy, or man, with a gun and no game.

Flicker. The flicker, commonly known as the yellow-hammer or golden-winged woodpecker, is at present the most common of our woodpeckers in Polk county. His season with us, as is also the case with the red-head, is from March to November. This is the largest bird of his tribe in this locality, and does a vast amount of good to the farmer and to humanity in general by destroying countless numbers of insects.

The flicker may be found anywhere throughout the residence districts of our city and everywhere in the country, feeding on the trunks of dead trees and decaying stumps, or on the ground like a pigeon.

ORDER COCCYGES: CUCKOS, KINGFISHERS, ETC.

Yellow-billed Cuckoo. We now come to another shy bird of the quiet woodland. The yellow-billed cuckoo is a beautiful, soft colored bird of secretive habits, and for that reason, not often met with.

Being very fond of the tent-worms and their moths, it is frequently to be found in orchards where these worms have gotten a start.

Its nest is a flat platform of a few sticks loosely laid together, placed in a bush.

This cuckoo's stay in Polk county is from April until October, and its winter months are spent in the valley of the Amazon.

Black-billed Cockoo: "Rain Crow." Like the yellow-billed species in all its habits, this bird needs no further description. It is, however, more common in Polk county than the yellow-billed.

Belted Kingfisher. A relative of the cuckoo, though almost its opposite in everything visible, this dashing, noisy, fearless chap is a common resident here from early March until late November, and can be found anywhere along our rivers and many of the smaller creeks.

His home is in a hollow tree or in an earth-burrow from six to eight feet deep in some high embankment along a river or railroad cut.

ORDER, RAPTORES: BIRDS OF PREY.

American Barn Owl. Not a very common owl, and yet one that is frequently met with in this part of the state is the American barn owl.

It is a harmless bird, feeding on mice, moles, large beetles, etc., and building its nest in barns, belfries, towers, etc. In wild regions it builds in hollow trees.

The owls are all yearly residents here.

Screech Owl. The most common of our Polk county owls is this little fellow, whose weird cry is so startling and uncanny on a still night.

Also a bird of prey, feeding on mice and moles to a large extent, this fellow is really a benefit to the farmer.

Great Horned Owl: "Hoot Owl." This great, wild, weird fellow is the most destructive of our owls, and his raids upon the chicken or turkey roost are very disastrous.

Now a comparatively rare bird in Polk county, he was once a very common resident, and made the nights hideous by his uncanny cries.

The hoot owl will be found now only in the deep, quiet woods where the trees are large and the underbrush thick. Here he still builds his nest in a hollow tree and captures rabbits and raids surrounding poultry yards for his food.

Marsh Hawk. This graceful "blue" hawk that is so often seen circling slowly over marshy lowlands is the most beneficial of its family, for it lives entirely on reptiles, locusts, grasshoppers, and small mammals, never touching poultry. It can see to hunt by night as well as by day, and is often hunting the most at that time.

The marsh hawk builds its nest on the ground in swampy meadows or among rushes in a marsh.

With us the marsh hawk's season is from early March until November, and in mild winters some of them winter here.

Sharp-shinned Hawk. Of this small, common hawk, Dr. Abbott says: "It is feathered lightning. He ceases to be before you realize that he is." Because of his wonderful swiftness and daring, this little hawk is about as destructive of poultry and song birds as the famous chicken hawk which I shall describe next.

A frequenter of all wooded districts, this little brigand builds his nest high up in a thick topped tree. The nest itself is a bulky platform of sticks with a nest of bark, leaves and moss in the center of the top. This hawk is a yearly resident.

Cooper's Hawk: Chicken Hawk. This exceedingly destructive hawk has become, in the last few years, much less common than formerly in Polk county, much to the advantage of the song birds and poultry.

This bird has not the dash and daring of the sharp-shinned hawk, but is one of the most crafty of our birds of prey. It is a shy bird, and, except where there are chickens, is seldom seen about dwellings, but in and about the wooded strips. Its nest is built in the tops of trees in the thick woods and resembles that of the last named species.

During April of 1856 or 1857 a great migratory flight of these hawks was noted, in which hundreds of thousands of the birds were seen to pass over northwest Des Moines in a single day. They flew in flocks like ducks, one flock within easy sight of several others in the general flight and occasionally a hungry hawk was seen to drop suddenly from the flock into a chicken yard below.

Red-tailed Hawk: Hen Hawk. The great red-tailed hawk is the most common of our big hawks, and it is the one that scatters the hens in wild confusion upon its appearance, for this hawk is easily capable of carrying off a good sized hen. However, it is said that eighty per cent of its food consists of rodents, destructive to agriculture.

Its nest is built, as the last one just described, in the top of a tall tree in the deep woods, and there are a few nests to be found every year in Polk county.

Red-shouldered Hawk. A trifle smaller than the red-tailed, this other of our big hawks is not quite so often met with in Polk county as is its larger cousin. It is a dignified bird with an owl-like flight but majestic, eagle-like pose when at rest.

It is also a bird of the deep woods, though it often hunts, as does the marsh hawk, about the marshes where frogs are abundant.

Bald Eagle. No longer found resident in Polk county, though occasionally seen here and found nesting in other parts of Iowa, the bald eagle cannot be left out of a treatise on birds without a feeling of incompleteness.

This majestic bird was often found here by the early residents in this section, and in honor to our nation and justice to our state, I take the liberty of this much mention of him, and of suggesting that, while we feel a sentimental regret that the great bald eagle is no longer found here, perhaps it is fortunate for our farmers that this bullying robber is no longer among us.

American Sparrow Hawk. This, the smallest and prettiest of our hawks, is also one of the most useful, living on rodents and large insects, with an occasional song bird or sparrow.

In the country districts throughout Polk county, this little fellow can be frequently met with along the roads and near groves or wooded strips.

Rarely a resident, this hawk comes to us usually in March and goes again late in November. Its nest is built in a hollow tree or old woodpecker's hole, and in fact, sometimes in dove-cots.

American Osprey: Fish Hawk. One of our most interesting birds of prey, the fish hawk is much less common than formerly in Polk county, though in other parts of Iowa it is still a familiar sight along our rivers.

Living almost entirely on fish, which it catches in its large, strong talons, this daring fellow will dive quite deep at times to secure its prey. After such a dive it will frequently emerge from the water, shake a shower of spray from its wings and rise slowly, carrying a five or six pound bass to a convenient tree or high bank where it is consumed.

Although a resident here, the osprey is seen most frequently in the spring and early fall (its season with us is from April to November).

This eagle-like bird builds its bulky nest in a high tree near or over water, and frequently in almost inaccessible places.

Turkey Vulture: Turkey Buzzard. Only twice have I seen these great scavenger birds in Polk county, and, since the time has come when carrion is no longer left lying about on our prairies or in the timberland of our well settled county, they will never become again, as they once were, familiar residents in this part of the state. Thirty years ago the turkey vulture was as common a resident of Polk county as is the crow today. The vulture's favorite means of defense was to vomit on the besieging enemy.

ORDER, COLUMBAE: PIGEONS.

Passenger Pigeons. Forty years ago the wild pigeon was probably the most abundant of our game-birds and migrated in immense flocks that blackened the sky as they flew over. Today they are so rare that every appearance is carefully noted. Once only in the past fourteen years of observation have I seen the passenger pigeon in Polk county, Iowa, where once they were killed by the hundreds and left lying as food for the pigs, while others were hauled by the wagon load into our city and shipped to larger places.

The woodcock has already gone the way of the wild pigeon, and the quail, prairie chicken, grouse and snipe are in grave danger of the same fate. Let us do all possible to create sentiment and enact laws that will protect them before it is to late.

Mourning Dove. These shy but sociable birds are very common in Polk county. Naturally a bird of the quiet woods, they are also found nesting in the residence portions of our city and in nearly every farm yard.

The nest is a loose bunch of sticks thrown together to form a transparent platform on a horizontal branch of almost any kind of a tree, though a pine or evergreen is preferred.

The season here is from March to late November.

ORDER, GALLINAE: GALLINACEOUS BIRDS.

Bob-white: Quail. Beginning with the bob-white I shall give only a brief statement regarding each of our more common game-birds and water birds. They are all rapidly becoming rare birds in Polk county as summer residents, and I shall merely try to give a few suggestions as to where they can yet be found.

The bob-white is a yearly resident with us and can be found best in the spring and early summer in the quiet, open woods where there is considerable underbrush but not a thick growth of timber. In the fall they are often met with in flocks in the fields or woods, but because of the man with the gun are very wild at that time. Their nesting habits are like those of our domestic chickens except that the nest is located in a very quiet, secluded spot, as far as possible from the houses or places of labor of man.

Ruffed Grouse: (Pheasant). A bird of the deep, quiet woods, this magnificent drummer is still sometimes met with in Polk county. The ruffed grouse is also most easily found in the spring, early April being the best month. Only in the deep woods will he now be found, and mostly northwest of Des Moines, in the wooded hills near the Des Moines river or Beaver creek.

Prairie Hen: "Prairie Chicken." More common than the ruffed grouse in this county, we will meet with the prairie hen most often near or in the edge of a grain field near a brush-covered hill or a thick wooded strip. Also a yearly resident, the prairie chicken is seen in the early fall in flocks of from fifteen to fifty, flying from field to field where food is to be found at that time of year. Its nesting habits are also like those of the domestic fowl.

ORDER, LIMICOLAE: SHORE BIRDS.

Kildeer Plover. Recognized by its cry, the killdeer plover is abundant one year and very rare the next along our streams and marshes. It nests in swampy meadows, arriving in March and not leaving until late November. It is most easily found in early spring and late summer.

American Woodcock. The king of our game-birds, the American woodcock is a thing of the past in Iowa, another tribute to the greed of the American hunter, for this bird was also once a well known bird in these parts.

I have only found the woodcock twice in Polk county, both of those times along the river in the woods between Camp Douglas and the mouth of Beaver creek.

Spotted Sandpiper: "Teeter." As yet a common bird in Polk county, the spotted sandpiper may be found from April until late October along nearly any of our roadside or woodland brooks, and along the rivers and larger creeks.

The nest of this sandpiper is to be found in such a location as is chosen by the meadow-lark.

ORDER, PALUDICOLAE: CRANES, RAILS, ETC.

American Coot: Mud Hen. Still a comparatively common bird about our swampy ponds and river bottoms, the mud hen is known by all the hunters and the boys who spend much time in those places. Arriving here early in March, the mud hen stays until late October or November, building its nest on a decayed reed bed in a swamp or on a mucky tussock in a marshy place where the eggs and young are always damp.

ORDER, HERODIONES: HERONS, ETC.

American Bittern: Stake Driver. An evil looking inhabitant of the great, lonely marshes, the American bittern is probably almost excluded from Polk county because of the tiling out of all our bigger swamps. Its season in Iowa is from May to November, and if found any more in Polk county, it will be along our river bottom marshes. I have found it a number of times here, though not in the past three years.

Least Bittern. The smallest of its family is still a rather common bird in some of our meadow marshes. It is very hard to find because of its great shyness and is always in seclusion near tall reeds or cat tails. Most of our bird students will not find this peculiar little fellow in spite of his comparative abundance.

Great Blue Heron: Blue Crane. One of the most picturesque as well as the largest resident bird of Iowa, the great blue heron has in the past few years ceased to reside in Polk county for the same reason as the American bittern. Naturally a very shy, suspicious bird, accustomed to the great, lonely marshes and pond filled meadows, this bird has sought more agreeable locations for nesting.

In the early spring and late fall it may yet be seen along our rivers or near our larger ponds where it may make a brief stop in its migratory journey.

Green Heron: "Poke." This heron is common in Polk county, and I have several times found one or two pairs in the marshes along the Highland Park car line just north of the river. Most of our marshes contain one or several pairs, and they are not hard to find.

Their nests are placed in trees not far from the ground, and are large, bulky structures of sticks and bark.

Little Blue Heron. Not different from the green heron, but much less common here.

Black-crowned Night Heron. Not so common as the green heron and yet not uncommon, this nocturnal member of the heron tribe will be most often seen in the evening about dusk, flying slowly from its roost or nesting place in the quiet woods, to some marsh or pond where it will spend the night in quest of food.

These birds often nest in colonies, though I have never found it so in Iowa.

ORDER ANSERES: LAMELLITROSTRAL SWIMMERS.

Mallard. Once a frequent resident of Polk county, but now confined to the larger lakes and mostly to more northern latitudes, this progenitor of our tame ducks is well known as a game-bird, and is to be seen every spring and fall at the time of the migrations.

Blue-winged Teal. Less common in the migrations than the green-winged variety, but more common as a summer resident, this duck may often be found nesting near our isolated ponds where wild-grass meadows surround them. The migrations are in early March and November.

Green-winged Teal. Not different in habits from the species just described.

Wood Duck: Summer Duck. This is the most beautiful of our native ducks, and of late years has also become the most rare. In fact, I have once seen the wood duck in Polk county, and can find very few persons who have found it here within the past five years. This is only another example of the story being so often repeated in our land, of local extermination preceding the general extermination of our once common, beautiful birds. The wood-duck, unlike all others of its family, builds a feather-lined nest in the hollow of a partly decayed tree near the water and at quite a distance from the ground. From this nest the young are carried in the parent birds' bills to the water's edge.

ORDER PYGOPODES: DIVING BIRDS.

Pied-billed Grebe: Hell-diver. This common little fellow can dive at the flash of a gun and be beyond harm before the charge fired has reached its mark.

In many ways its eastern name of "dabchick" is most descriptive, for its nest resembles a mud pancake floating on a bed of rushes and covered, in the day time when the sun shines, with a layer of muck which is scraped off at night and the eggs incubated.

The pied-billed grebe is a common summer resident in our marshes and ponds, and can generally be found with little difficulty.

LIST OF BIRDS TREATED BY FAMILIES.

Order Passeres: Perching Birds.
Sub-Order Oscines: Singing Birds.
Family Turdidae: Thrushes
American Robin
Wood Thrush
Wilson's Thrush: Veery
Blue Bird
Family Paridae: Nut-hatches and Titmice
Chickadee
White-breasted Nut-hatch
Red-breasted Nut-hatch
Family Troglodytidae: Wrens, Thrashers, etc.
Cat-bird
House Wren
Long-billed Marsh Wren
Short-billed Marsh Wren
Family Mniotiltidae: Wood Warblers
Black and White Warbler
Yellow Warbler
Chestnut-sided Warbler
Prairie Warbler
Ovenbird: Golden-crowned Thrush
Maryland Yellow-throat
Yellow-breasted Chat
American Redstart
Family Vireonidae: Vireos
Red-eyed Vireo
White-eyed Vireo
Warbling Vireo
Family Laniidae: Shrikes
Loggerhead Shrike
Family Ampelidae: Waxwings
Cedar Waxwing

Order Passeres: Perching Birds.
Family Hirundinidae: Swallows
Purple Martin
Barn Swallow
Tree Swallow
Bank Swallow
Eaves Swallow: Cliff Swallow

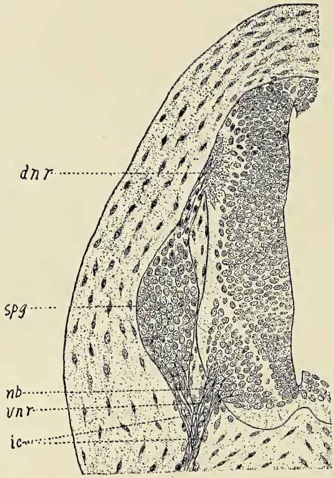
Family Tanagridae: Tanagers
Scarlet Tanager

Family Fringillidae: Finches, Sparrows, Grosbeaks
English Sparrow
Vesper Sparrow
Chipping Sparrow
Song Sparrow
Field Sparrow
Swamp Song Sparrow
American Goldfinch
Towhee
Cardinal
Rose-breasted Grosbeak
Indigo Bunting
Family Icteridae: Blackbirds, Orioles, etc.
Bobolink
Cowbird
Red Winged Blackbird
Rusty Blackbird
Bronzed Grackle
Yellow-headed Blackbird
Meadow Lark
Baltimore Oriole
Orchard Oriole

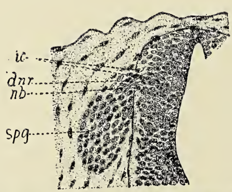
LIST OF BIRDS TREATED BY FAMILIES—CONTINUED.

Order Passeres: Perching Birds.
  Family Corvidae: Crows, Jays, Magpies
    Blue Jay
    American Crow
  Sub-Order Clamatores: Songless Perching Birds
  Family Tyrannidae: Tyrant Flycatchers
    Kingbird
    Great Crested Fylcatcher
    Phoebe
    Wood Pewee
    Least Flycatcher
Order Macrochires: Swifts, Whip-poor-wills, etc.
  Family Caprinsulgidae: Goatsuckers
    Whip-poor-will
    Night Hawk
  Family Micropodidae: Swifts
    Chimney Swift
  Family Trochicidae: Humming-birds
    Ruby-throated Humming-bird
Order Pici: Woodpeckers
  Family Picidae: Woodpeckers
    Hairy Woodpecker
    Downy Woodpecker
    Yellow-bellied Sapsucker
    Red-headed Woodpecker
    Flicker
Order Coccyges: Cuckoos, Kingfishers, etc.
  Family Cuculidae: Cuckoos
    Yellow-billed Cuckoo
    Black-billed Cuckoo
  Family Acedinidae: Kingfishers
    Belted Kingfisher
Order Raptores: Birds of Prey
  Family Strigidae: Barn Owls
    American Barn Owl
  Family Burdonidae: Horned Owls
    Screech Owl
    Great Horned Owl: Hoot Owl
  Family Falconidae: Falcons, Hawks, Eagles
    Marsh Hawk
    Sharp-shinned Hawk
    Cooper's Hawk: Chicken Hawk
    Red-tailed Hawk

Order Raporte: Birds of Prey.
  Family Falconidae:
    Red Shouldered Hawk
    Sparrow Hawk
    American Osprey: Fish Hawk
    Bald Eagle
  Family Vultures
    Turkey Vulture
Order Columbae: Pigeons
  Family Columbidae: Doves and Pigeons
    Passenger Pigeon
    Mourning Dove
Order Gallinae: Gallinaceous Birds
  Family Tetraonidae: Grouse, Partridges, etc.
    Bob-white: Quail
    Ruffed Grouse
    Prairie Hen
Order Limicolae: Shore Birds
  Family Charadriidae: Plovers
    Kill-deer Plover
  Family Scolopacidae: Snipes, Sandpipers, etc.
    American Woodcock
    Spotted Sandpiper
Order Paludicolae: Cranes, Rails, etc.
  Family Rallidae: Rails, Gallinules, Coots
    American Coot: Mud Hen
Order Herodiones: Herons, etc.
  Family Ardeidae: Herons, Bitterns, etc.
    American Bittern
    Least Bittern
    Great Blue Heron
    Green Heron
    Little Blue Heron
    Black-Crowned Night Heron
Order Anseres: Lamellirostral Swimmers
  Family Anitidae: Ducks, Geese, etc.
    Mallard
    Green-winged Teal
    Blue Winged Teal
    Wood Duck
Order Pygopodes: Diving Birds
  Family Podicipidae: Grebes
    Pied-Billed Grebe: Hell-diver



Migration of Nervous Elements



Migration of Nervous Elements.

THE MIGRATION OF NERVOUS ELEMENTS INTO THE DORSAL AND VENTRAL NERVE-ROOTS OF EMBRYOS OF THE PIG.*

BY ALBERT KUNTZ.

With two Figures.

That nervous elements migrate peripherally from the neural tube, during early embryonic development, has been observed by several investigators. Harrison ('01) called attention to medullary cells migrating into the ventral nerve-roots of embryos of the salmon. Bardeen ('03) observed that "in mammals, as well as in the lower vertebrates, a certain number of cells wander out from the spinal ganglia and cord along with the bundles of axis-cylinder processes." In his work on embryos of the chick, Carpenter ('06) has shown that cells of an indifferent character migrate from the ventral wall of the mid-brain along the oculomotor nerve and become transformed into nerve cells of the ciliary ganglion. In a more recent paper Carpenter and Main ('07) have described the migration of medullary cells into the ventral nerve-roots of embryos of the pig.

In his study of the earliest differentiations in the central nervous system, Schaper ('97) has shown that the germ cells (Keinzellen) of His cells of epiblastic origin undergoing mitotic division near the internal limiting membrane of the medullary tube—give rise to cells which he characterizes as indifferent, which migrate toward the mantle layer and are there transformed either into neuroblasts or into embryonic supporting cells. In the higher vertebrates some of these indifferent cells undergo further division by mitosis in the mantle layer, thus giving rise to other indifferent cells after having migrated from their original position.

In the cells which Carpenter and Main observed migrating into the ventral nerve-roots of embryos of the pig, they have recognized the indifferent cells of Schaper.

In studying embryos of the pig for the purpose of tracing the development of the sympathetic nervous system, the writer has observed medullary cells migrating into both ventral and dorsal nerve-roots. In transverse sections of embryos of the pig from 9 to 13 mm. in length, breaches of considerable extent in the external limiting membrane of the medullary tube may be observed in the region of the ventral nerve-roots. Among the fibers of the nerve-roots passing through these breaches cells may be observed migrating out from the neural tube (fig. I). I have been able to substantiate the observation of Carpenter and Main that cells may be found "just inside the external limiting membrane, in an intermediate position half in and half out of the neural tube, and in the base of the nerve-root just outside the external limiting membrane."

*From the Laboratories of Animal Biology of the State University of Iowa.

Among these migrating cells I also recognize, as did they, the indifferent cells of Schaper. In several sections, however, cells with large rounded or elongated nuclei and cytoplasm drawn out to a point at one side were observed among the fibers of the ventral nerve-root, migrating with the indifferent cells. In these cells I recognize the neuroblasts of Schaper. They are much fewer in number than the indifferent cells but are distributed indiscriminately among them. When observed in the spinal nerve-roots the tapering end is usually directed peripherally. This, also, is in accordance with the usual position of the neuroblasts in the mantle layer. The orientation of the cells in the neural tube is such that two general courses of migration into the ventral nerve-root may be recognized; the one directly outward from the ventral zone; the other ventro-laterally toward the base of the nerve-root, from the region in which later the lateral horn of the gray matter arises.

In transverse sections of embryos of the pig 6 and 7 mm. long, breaches in the external limiting membrane of the neural tube occur quite frequently in the region of the dorsal nerve-root. Through these breaches medullary cells migrate so freely that in many sections lines of cells practically touching each other end to end can be traced from the mantle layer into the proximal part of the dorsal nerve-root (fig. II). Further evidence for the migration of medullary cells into the dorsal nerve-roots is seen in the fact that in many sections of embryos 6 and 7 mm. long, where no breaches occur, cells are found in contact with the external limiting membrane in the region of the dorsal nerve-root. In embryos 9 mm. and over in length this area, as shown in fig. I, is always occupied by fibers of the dorsal nerve-root, and rarely are cells found among them. Two general courses of migration may also be recognized in the dorsal region. One of these courses has its origin in the dorsal zone. Some of its cells move in a slight curve directly toward the dorsal nerve-root, others pass from the most dorsal region along the inner surface of the external limiting membrane. The other course tends dorso-laterally from regions ventral to the dorsal nerve-root. The cells of the latter course probably originate in the same region as those which move ventro-laterally toward the ventral nerve-root.

Among the cells migrating into the dorsal nerve-roots, I recognize both the "indifferent cells" and the "neuroblasts" of Schaper.

My observations do not permit me to conclude how early the first migration of cells from the neural tube takes place. In studying a very young embryo in which, however, the external limiting membrane was completely formed, no migrating cells could be observed. It is probable, therefore, that cells do not migrate out of the neural tube until the fibers of the nerve-roots have penetrated the external limiting membrane.

As observed above, cells are rarely found among the fibers of the dorsal nerve-root near the external limiting membrane inside the neural tube, in embryos 9 mm. and over in length. Migration into the dorsal nerve-root probably ceases before a length of 9 mm. is reached. Migration into the ventral nerve-root continues longer and seems to be most active in embryos from 10 to 13 mm. in length. In embryos over 13 mm. in length migration is rarely observed and probably does not continue far beyond that stage.

There are four points to which the writer wishes to call special attention in this paper. (1) Medullary cells migrate into both dorsal and ventral nerve-roots. (2) These migrating cells seem to have their origin in more or less definite regions in the neural tube. (3) Migration from the neural tube seems to be limited to a comparatively short period during embryonic development. (4) While the majority of the cells which migrate into the dorsal and ventral nerve-roots are cells of an indifferent character, cells may be recognized among them, which are to be regarded as the neuroblasts of Schaper.

These observations give rise to an important question. What is the destiny of those cells which migrate from the neural tube into the dorsal and ventral nerve roots? This question the writer hopes to consider more fully in a later paper. But, as the way has been opened for a priori speculation a few suggestions may be ventured here.

Harrison ('01) has already suggested the possibility that the medullary cells which he saw migrating into the ventral nerve-roots of embryos of the salmon may wander farther peripherally, i. e., into the sympathetic ganglia, and there give rise to sympathetic motor neurones. Bardeen ('03) suggests that the cells which wander out from the spinal ganglia and cord along with the bundles of axis-cylinder processes of the nerve-roots may take some part in the formation of the neurilemma, but believes with Vignal and Gurwitsch that in mammals the cells composing the neurilemma arise largely from mesenchyme. Harrison's experimental observations on the tadpole ('06) seem to prove that some of the elongated cells found among the fibers of developing nerves, which become cells of the neurilemma, are derived from spinal ganglia. Carpenter and Main ('07) "feel sure" that some of the medullary cells which escape from the neural tube become cells of the neurilemma, and there subserve a supporting function similar to that of the neuroglia cells in the central nervous system.

Thus far only cells of an indifferent character have been considered. May not the fact that neuroblasts migrate with the indifferent cells into both dorsal and ventral nerve-roots shed some new light on the entire problem? To trace these cells to their ultimate destination is a matter of extreme difficulty, if not impossibility, with the aid of present staining methods alone. In the light of Schaper's researches, however, we must conclude that the neuroblasts which migrate into the dorsal and ventral nerve-roots have already undergone differentation and must develop into neurones. Having once passed beyond the borders of the neural tube they must migrate farther peripherally. Nothing seems more probable, therefore, than that they should wander along the visceral ramus and give rise to neurones in the sympathetic ganglia. Any conclusion, however, on this point would at present be hasty. We feel that these migrant cells, both the "indifferent cells" and the "neuroblasts" of Schaper, are fraught with great potentialities and invite the most careful scrutiny into their fate.

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EXPLANATION OF FIGURES.

Fib. I. Transverse section of neural tube and spinal ganglion of a 12 mm. embryo of the pig. XI65.
dnr—dorsal nerve root. spg—spinal ganglion. nb—neuroblast. vnr—ventral nerve-root. ic—indifferent cells.

Fig. II. Transverse section of neural tube and spinal ganglion of a 6 mm. embryo of the pig. XI65.
ic—indifferent cells. dnr—dorsal nerve-root. nb—neuroblast. spg—spinal ganglion.

SOME OBSERVATIONS ON THE EMBRYOLOGY OF CHIRONOMUS.

BY W. N. CRAVEN.

A. INTRODUCTION—TIME AND PLACE OF LAYING.

All the eggs used in the following investigation were collected from a small pond in the eastern edge of the city of Indianola. The eggs were gathered from time to time at intervals of from one to three days, between June 20th and September 30th, 1902. They were found in abundance along the bank, in water from one to six inches deep. Usually they were attached to a piece of wood, or some plant growing in the edge of the water. Many were also found attached to the bottom. A few were found floating in the water, but as by far the greater number were attached, it is probable that those found floating had broken from their attachment, or by some accident had not been fastened.

It was found that the eggs collected in the early morning were always considerably advanced in their development; so that some of them must have been deposited the previous day. Those collected in the early afternoon were always at least in the early stages of development, while the most freshly laid eggs were collected about ten o'clock A. M. As the insects were always present about the edges of the pond in the early morning, it is probable that some little time, perhaps two or three hours, were consumed in depositing and fastening an egg mass. It is probable that the greater number were laid in the early morning—before ten A. M. As all the eggs in which the first stages of development had been reached were found about noon, by far the greater number must have been deposited in the early morning.

B. THE EGG MASS.

The eggs are laid in a clear jelly like mass, which is about three-eighths of an inch in diameter and varying from one-fourth to three-fourths, or sometimes nearly an inch in length. The egg mass was always attached by one end, and since its specific gravity is less than that of water, it assumes a nearly vertical position in the water. The eggs are arranged in the mass in the form of a spiral, which runs the length of the mass. The eggs are placed with their long axes in the line of the spiral, each egg lying slightly above and its end projecting over its predecessor. Hence in the normal position of the eggs in the water the embryo lies with its long axis nearly horizontal.

C. TIME OF INCUBATION.

The time of incubation varied considerably for different egg-masses, although those of the same egg mass always hatched within two or three hours of the same time.

The shortest period in which any hatched was about seventy-five hours; the longest period was about 110 hours. The time of incubation seemed to depend almost entirely upon the temperature and sunshine. Those kept at a temperature above 80 degrees F. and in the sunshine developed most rapidly, while those which were away from the light and cooler developed more slowly.

In those egg masses which were kept in conditions such that they developed more slowly there were found more eggs which did not hatch. This would seem to indicate that any considerable reduction of temperature or deprivation of sunlight would entirely prevent development. No accurate observations were made, however, upon this point.

D. THE EGG.

The eggs are elongated-oval appearing slightly larger at the extremity which is to become the anterior, when viewed dorso-ventrally. When viewed from the side they appear more convex on the side which is to become the ventral, the dorsal side in the majority of cases appearing slightly concave, through part of its length. (See fig.)

The eggs vary somewhat in size. From a number of measurements, the average size was found to be very close to 1-21 inch in length by 1-50 inch in thickness. From these measurements individual eggs varied as much as 1-240 inch in length and 1-500 inch in thickness, or very nearly 10 per cent.

The choroin is perfectly transparent, and somewhat flexible, allowing the egg to be distorted by pressure from the cover glass, without breaking. After hatching the empty shell was quite flexible. No micropile was observed.

The vitelline membrane does not fit against the choroin at all points, but is drawn away at the ends, usually more at the posterior end.

The egg contents are composed almost entirely of the nutritive yolk substance. There is very little of the outer protoplasmic layer present (keimhautblasten of Weisman). The yolk has a yellowish green color, is very granular, and highly refractive. Numerous oil globules of varying size can be seen scattered through it. In some of the eggs collected late in the season the yolk had a more brownish color. They seemed to be identical with those previously obtained in other respects. Only a few of these were obtained and it was not determined whether they belonged to different species, or the change in color was due to the lateness of the season.

E. EARLY STAGES IN DEVELOPMENT.

The first change noticeable was a slight drawing in of the vitelline membrane at each end. Shortly afterward there appeared at the anterior end four rather large, quite granular cells (Pl. 1, fig. 1-a). About an hour later other cells not so large began to appear on the surface of the yolk. These form a layer (Pl. 1, fig. 2) which increases in thickness and number of cells by addition from within, until an irregular layer of cells, the blastoderm, of comparatively considerable thickness, covers the entire surface (Pl. I, fig 3.) The cells then arrange themselves regularly and form a layer of columnar cells, the blastoderm covering the yolk. During these changes the large cells are at all times distinctly visible at the anterior end of the egg (Pl. 1, figs. 2, 3 and 4-a). When the formation of the blastoderm begins, the egg contents crowd out to the end, entirely filling the cavity of the shell.

There next appears at the dorsal, anterior end, a thickening of the cell layer, by addition of new cells beneath the surface layer (Pl. I, fig. 5-p). This is the beginning of the primitive band. At the same time the blastoderm begins to fold in above this point, and as the cells underneath increase in number the fold pushes them downward and backward (Pl. I, figs. 7 and 8.)

While the above changes are taking place the cells of the blastoderm crowd away from the sides, so that now it forms a band completely surrounding the egg. A dorsal view of this stage is seen in Plate II, figure 3.

The fold noticed above makes the first segment of the embryo, the procephalic lobes. It is pushed around to the ventral side of the embryo (Pl. II, figs. 4 and 5) and at the same time the ventral part of the fold becomes constricted laterally. Plate II, figures 1 and 2, are diagrams showing the relations of the parts of the fold, at this time, as viewed from the dorsal and ventral aspects respectively. The sides are next folded in in the line of the groove so that in ventral and dorsal views the procephalic lobe is plainly visible (Pl. II, figs. 6 and 7). A little later the infolding of the primitive band to form the stomodoeum begins, and at the same time a longitudinal groove, the gastrula invagination, extends along its ventral side. Plate II, figure 6-g, represents the first beginning of the gastrula infolding.

F. FORMATION OF THE SEGMENTS.

Following the gastrula invagination, and the formation of the procephalic lobes, the primitive band grows rapidly backward. The yolk is pushed up to the dorsal side, and the embryo lies as a band extending about the egg but not meeting on the dorsal side. As the primitive band extends backward from the procephalic lobes it becomes constricted by transverse furrows which divide it into segments. The mandibular segment is the first to appear, then the first and second maxillary segments. Following these, the segments appear in a general way in succession from before backward. Frequently, however, two or three segments seem to be formed almost simultaneously.

G. THE PROCEPHALIC LOBES.

In the first place the procephalic lobes are represented by a somewhat globular fold at the anterior end of the primitive band (Pl. II, figs. 6 and 7). There soon appears on the ventral median surface on the fold a depression (Pl. II, fig. 8-a). As this deepens the anterior wall of the lobes is thickened and the lateral portions are pushed backward, forming a slight fold so that the procephalic lobes proper become smaller in size. The mandibular segment crowds forward on each side apparently absorbing this fold.

H. THE APPENDAGES.

(*a*) *The antennae.*

The antennæ appear as buds from the base of the procephalic lobes just in front of the mandibular segment. They are first noticeable as small projections near the dorsal part of the head (Pl. III, fig. 2-a). This takes place about the 30th hour of incubation. The antennal bud grows downward along the side of the head fold and in front of the mandibular segment, becoming somewhat thicker at the same time (Pl. III, a). The segments do not appear in the antennæ until near the close of embryonic life. They then appear as constrictions of the already formed antennæ, not by the addition of segments from behind. At the close of embryonic life the antennæ are composed of three segments (Pl. III, figs. 10 and 12-a).

(*b*) *The mandibles.*

The mandibles appear as appendages of the second segment. This segment is divided laterally into two parts, by the appearance of the gastrula invagination and the stomodoeum, almost as soon as it appears (Pl. II, fig. 8). Almost immediately the two lobes move forward to the sides of the antennal segment (Pl. II, fig. 10-m). As the embryo develops these rudimentary mandibles become narrower and longer (Pl. III, figs. 5 and 7-md.) About six or eight hours before the time of hatching they have grown downward and are visible in a ventral view of the embryo (Pl. III, figs. 5 and 7 md.) A short time before hatching they become divided into two segments by a very slight constriction, and the distal segment develops into a sharp pointed organ. This is the larval mandible.

(*c*) *The maxillae.*

The first maxillæ develop as appendages of the third segment. This segment, like the mandibular segment, becomes divided by a dorso-ventral constriction almost as soon as it is formed, and begins to move forward as two lobes, which constitute the rudimentary appendages and their attachment. The anterior edge of this segment moves forward until it is slightly in front of and outside the posterior edge of the procephalic lobes. (Pl. III, figs. 2, 3 and 6, 1st mx.) The maxillæ grow downward and inward (Pl. III, fig. 11, 1st mx.), and just before the close of embryonic life a small segment is formed at the end. In the newly hatched larva there is visible a third, very small segment at the extremity of the maxillæ.

The second maxillæ are very little developed. They appear as slight protuberances of the fourth segment. They are noticeable just before hatching (Pl. II, fig. 11-m).

(*d*) *The thoracic appendages.*

No appendages are visible upon the thoracic segments until near the close of embryonic life. About eight to ten hours before hatching there appear upon the first thoracic segment a pair of appendages. These are not as yet segmented and lie close together on the ventral surface of the embryo (Pl. III, figs. 8, 10, 11 f.) These develop into blunt rounded appendages, upon the surface of which there appear, just before hatching, a number of setæ. These are noticeable in figures 8, 10, 11 and 12, Plate III. They serve as legs during the larval life of the insect.

(*e*) *Abdominal appendages.*

No abdominal legs were observed at any time. On the ventral surface of the last segment, however, appear a pair of large tubular appendages, fringed with a circle of cilia about their external opening. These are in connection with the tracheal system, a tube from which extends along their entire length, opening at the distal extremity. They serve as larval respiratory organs. They may be seen in the embryo in figure 7, Plate III, r., and in the newly hatched larva.

DESCRIPTION OF PLATE I.

Fig. 1. The egg 2 or 3 hrs. after laying. (a) Large cells which later develop into the reproductive organs.
Fig. 2. The eggs at about 2 or 4 hrs. showing the layer of blastodermal cells. (a) Large reproductive cells.
Fig. 3. The egg at about an hour later than in fig. 2, showing the thickened layer of blastodermal cells, and the large reproductive cells still visible at a.
Fig. 4. The egg at about the sixth hr. of incubation.
(a) reproductive cells.
(b) cells arranged in a columnar layer forming the blastoderm.
Fig. 5. The reproductive cells have retreated to the interior and are no longer visible. (p) The beginning of the primative band.
Figs. 6 and 7. A little later than 5, showing the first infolding of the blastoderm. (v) Vitelline membrane.
Fig. 8. Egg at about hr. of incubation. (v) Vitelline membrane. (p) Beginning of stomodoeum.

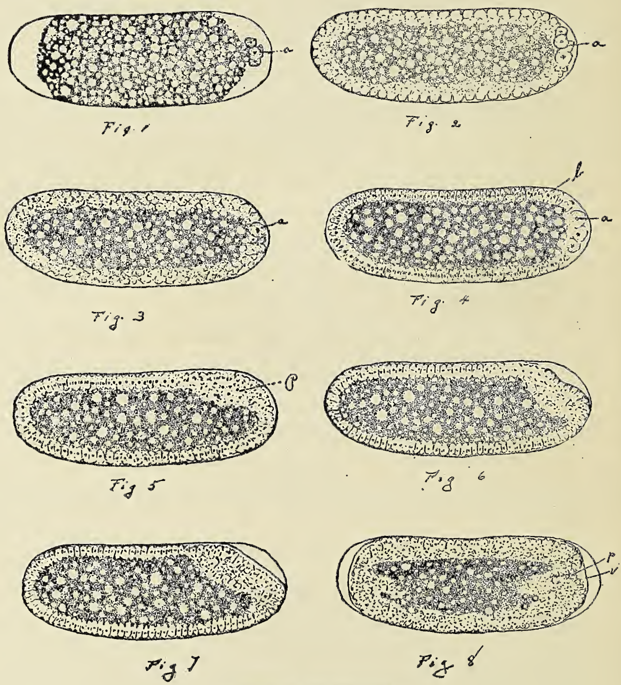
DECRIPTION OF PLATE II.

Figs. 1 and 2. Diagram showing the form of the first fold at the anterior end. In fig. 1 as viewed from the dorsal and fig. 2 as viewed from the ventral sides.
Fig. 3. Dorsal view at the same stage showing the yolk mass crowded to the sides, the blastoderm forming a complete dorso-ventral band.
Figs. 4 and 5. Showing the fold pushed to the ventral side and backwards.
Fig. 6. Ventral view of embryo. (p) procephalic lobe. (g) beginning of gastula invagination. (s) beginning of proctodoeum.
Fig. 7. Dorsal view of stage shown in fig. 6. (p) procephalic lobe. (s) proctodoeum.
Fig. 8. Egg at about eighth hr. of incubation. (v) Vitelline membrane. (p) Begin- (m) Mandibular segment. (g) Gastrula.
Figs. 9 and 10. Two views about 4 and 7 hrs. later than fig. 8, showing the divided mandibular segment (m) pushing upward on each side of the procephalic lobes and carrying with it the antennal point (a).
Fig. 11. Dorsal view of embryo at same stage as fig. 10.
Fig. 12. Ventral view of embryo at same stage as fig. 10. (m) Divided mandibular segment.

DESCRIPTION OF PLATE III.

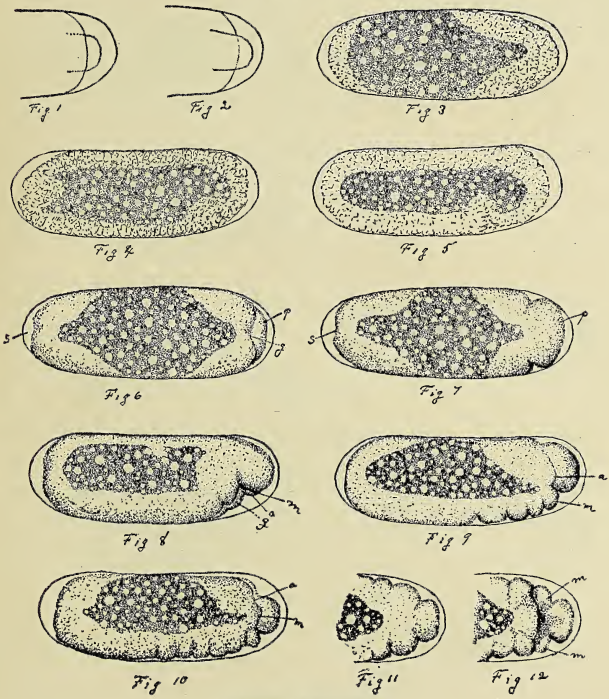
Figs. 1 and 2. Two views of the anterior part of the embryo at about 28 hrs-32 hrs. (a) antennae (md) mandibular segment. (1 mx). First maxillary segment. (2 mx) second maxillary segment.
Fig. 3. Side view of the entire embryo a little later than in fig. 2, showing thoracic and abdominal segments. Lettering as in fig. 2.
Figs. 4, 5, and 6. Dorsal and ventral views of the anterior portion of the embryo, and entire side view at about 40 to 45 hrs. Lettering as in fig. 2.
Fig. 7. Ventral view of embryo at about 55 hrs. to 60 hrs., showing mandibles beginning to form (md) and respiratory appendages at r.
Figs. 8 and 9. Side and ventral views about 5 hrs. later than fig. 7.
Figs. 10 and 12. Side and ventral views of the anterior and of the embryo just before hatching. Lettering as in figs. above.
Fig. 12. Side view of the entire embryo just before hatching.
Fig. 13. Optical section of embryo just before hatching, showing proctodoeum, stomodoeum, nerve-cord, and the still prominent sexual cells.

PLATE I



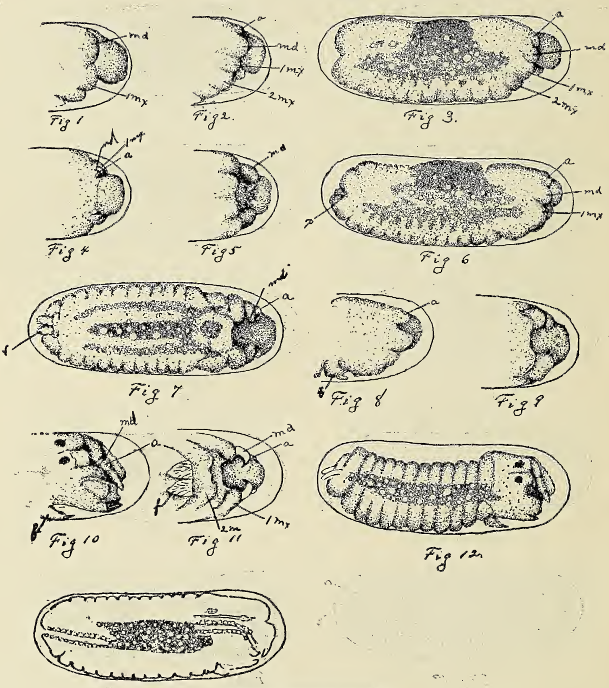
(Craven, Chironomus.)

PLATE II



(Craven. Chironomus.)

PLATE III



(Craven. Chiromonus.)

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