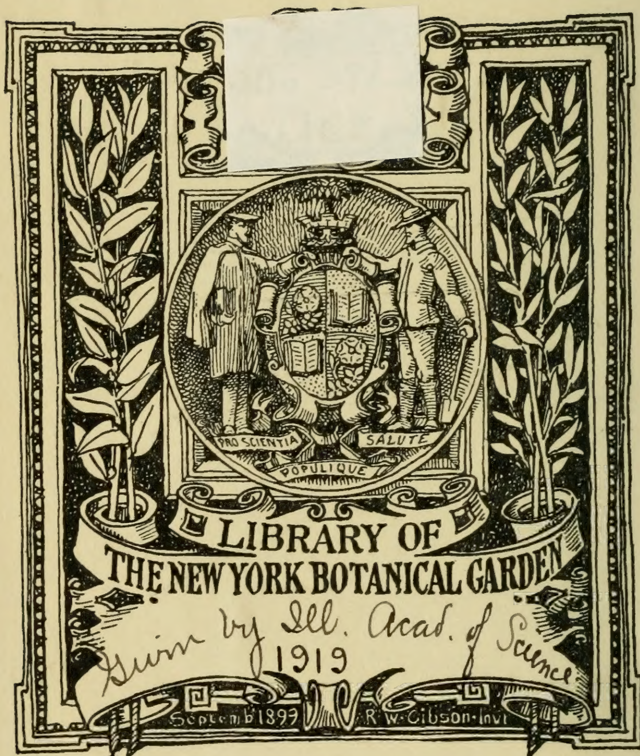
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TRANSACTIONS

OF THE

Illinois Academy of Science

SEVENTH ANNUAL MEETING

Evanston, Ill., Feb. 20 and 21, 1914

VOLUME VII

1914

PUBLISHED BY THE ACADEMY

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Edited By

A. R. Crook

1915–1916

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OFFICERS AND COMMITTEES FOR 1914-1915

President, A. R. Crook, Curator State Museum of Natural History, Springfield.
Vice-President, U. S. Grant, Northwestern University, Evanston.
Secretary, E. N. Transeau, State Normal School, Charleston.
Treasurer, John C. Hessler, James Millikin University, Decatur.

The Council

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Publication Committee

President, Secretary, Treasurer, and S. A. Forbes.

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H. C. Cowles, Chairman, Chicago.
Ruth Marshall, Rockford.
H. B. Shinn, Chicago.
Faith McAuley, St. Charles.
R. E. Wager, DeKalb.

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Alice Patterson, Normal.
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T. L. Hankinson, Charleston.

Committee on Calendar Reform

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A. R. Crook, Springfield.
C. G. Hopkins, Urbana.
E. J. Townsend, Urbana.
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Committee on Secondary Science.

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O. W. Caldwell, Chicago.

Committee on Ecological Survey.

S. A. Forbes, Chairman, Urbana.
H. C. Cowles, Chicago.
T. L. Hankinson, Charleston.
V. E. Shelford, Urbana.
E. N. Transeau, Charleston.
F. C. Baker, Chicago.
H. S. Pepoon, Chicago.
G. D. Fuller, Chicago.

PAST OFFICERS OF THE ACADEMY

1908

President, T. C. Chamberlin, University of Chicago.
Vice-President, Henry Crew, Northwestern University.
Secretary, A. R. Crook, State Museum of Natural History.
Treasurer, J. C. Hessler, James Millikin University.

1909

President, S. A. Forbes, University of Illinois.
Vice President, John M. Coulter, University of Chicago.
Secretary, A. R. Crook, State Museum of Natural History.
Treasurer, J. C. Hessler, James Millikin University.

1910

President, John M. Coulter, University of Chicago.
Vice-President, R. O. Graham, Illinois Wesleyan University.
Secretary, A. R. Crook, State Museum of Natural History.
Treasurer, J. C. Hessler, James Millikin University.

1911

President, W. A. Noyes, University of Illinois.
Vice-President, J. C. Udden, University of Texas.
Secretary, Frank C. Baker, Chicago Academy of Science.
Treasurer, J. C. Hessler, James Millikin University.

1912

President, Henry Crew, Northwestern University.
Vice-President, A. R. Crook, State Museum of Natural History.
Secretary, Otis W. Caldwell, University of Chicago.
Treasurer, J. C. Hessler, James Millikin University.

1913

President, Frank W. DeWolf, State Geological Survey.
Vice-President, H. S. Pepoon, Lake View High School, Chicago.
Secretary, E. N. Transeau, Eastern Illinois Normal School.
Treasurer, J. C. Hessler, James Millikin University.

Minutes of The Seventh Annual Meeting

Northwestern University
Evanston, Illinois, February 20-21, 1914

After call to order by President DeWolf, Professor Henry Crew of Northwestern University gave an address of welcome to which President DeWolf responded. This was followed by the President's address on "Recent Investigations of the Mineral Resources of the Country."

The following papers were then presented: "Earth Tides," A. A. Michelson; "The International Phytogeographical Excursion," Henry C. Cowles; "Recent Theories of Fertilization and Parthenogenesis," F. R. Lillie.

At six-thirty about one hundred members of the Academy were welcomed by President Harris of Northwestern University at a banquet in the University Gymnasium.

At eight o'clock the Northwestern Chapter of Sigma Xi gave a reception at Science Hall in the Physics Laboratory.

On Saturday morning, February 22, reports of the officers and committees were given, as follows:

THE SECRETARY'S REPORT

The sixth annual meeting of the Academy was held at Peoria, February 21 and 22, 1913, in the auditorium of the Bradley Polytechnic Institute. A Symposium on Sanitation was presented in the morning and a lecture by Prof. Barnard on "Some Late Results in Astronomical Photography," in the evening. The proceedings in full are given in Vol. VI. of the Academy's Transactions. At a meeting of the Council in the office of the Geological Survey, Urbana, November 22, 1913 it was decided to hold the seventh annual meeting at Northwestern University, February 20 and 21, 1914, and to recommend that the eighth annual meeting be held at Springfield. February 19 and 20, 1915. By having the place of meeting understood a year in advance it was thought that certain advantages would accrue to the Academy. The publication committee was authorized to proceed with the printing of the Transactions. Professor Forbes and President DeWolf were asked to draw up a legislative bill authorizing the State Board of Contracts to publish the Transactions of the Academy in the future. Professor J. S. Compton was elected a member subject to the approval of the Academy. Plans for the Evanston meeting were discussed.

Membership. At the Peoria meeting forty-six new members were added, making the mailing list for 1913 total 390 names—five less than during the preceding year. This number could readily be doubled if active members would each make an effort to secure at least one new member this year.

EDGAR N. TRANSEAU, Secretary.

COMMITTEES ON LEGISLATION, HIGH SCHOOL LEAFLETS AND HIGH SCHOOL SCIENCE

For the Committee on Legislation, Dr. A. R. Crook gave a verbal report.

The Committee on High School Leaflets, reported by way of a letter from Dr. John G. Coulter, that the plan of publication originally outlined by the committee would not pay if made a state affair.

As a report of the Committee on Pure and Applied Science in High Schools, W. W. Whitney, chairman, offered the two papers by H. B. Shinn and A. W. Nolan, which appear further along in the volume.

On motion of W. L. Eikenberry, the name of the Committee on Pure and Applied Science in High School was changed to Committee on Secondary Science. On motion of A. R. Crook it was decided to form a new committee on Calendar Reform. consisting of F. R. Moulton, chairman; A. R. Crook, C. G. Hopkins, E. J. Townsend and T. C. Chamberlin, the last named having requested to be relieved of the chairmanship.

The Auditing Committee, consisting of L. M. Umbach, G. D. Fuller and R. R. Tatnall, reported the books of the treasurer in good condition, and the statements as given in his report correct.

The Nominating Committee, consisting of C. B. Atwell, chairman, C. M. Turton, Ruth Marshall and J. L. Smith, made the following report of nominations for officers which was adopted by the Academy:

President—A. R. Crook, Springfield.

Vice-President—U. S. Grant, Evanston.

Secretary—E. N. Transeau, Charleston.

Treasurer, J. C. Hessler, Decatur.

Membership Committee—H. C. Cowles, chairman, Chicago; Ruth Marshall, Rockford, H. B. Shinn, Chicago, Faith McAuley, St. Charles, R. E. Wager, DeKalb.

Legislative Committee—A. R. Crook, Springfield, William Barnes, Decatur, Alice Patterson, Normal, E. O. Jordan, Chicago, T. L. Hankinson, Charleston.

In adopting the report of the Secretary the Academy voted to hold the meeting of 1915 in Springfield.

The Committee on Resolutions, consisting of F. C. Baker, chairman, offered the following resolutions which were unanimously adopted by the Academy:

Resolved, That the Illinois Academy of Science hereby expresses its appreciation and thanks for the cordial reception and the generous manner in which it has been entertained during the 1914 meeting by the president and the members of the faculties of the scientific department of the Northwestern University.

Resolved, That the Illinois Academy of Science hereby expresses its appreciation of the reception tended by the officers and members of the Northwestern Chapter of the Sigma Xi Society.

On motion duly seconded, the Seventh Annual meeting adjourned.

E. N. Transeau, Secretary.

REPORT OF THE TREASURER

February 20, 1914.

RECEIPTS

Balance on hand February 22, 1913	$ 88.82
Received from membership fees	195.00
Received from initiation fees	20.00
Received from exchange on checks	.25
Total receipts	$304.07

EXPENDITURES

To O. W. Caldwell, sec'y., postage and expenses attending Peoria meeting		$19.43
To University of Chicago Press, printing		11.75
To John C. Hessler, Treas., postage Nov. 26, 1912, to Feb. 21, 1913	$0.95	
Postage Feb. 26, 1913, to Dec. 29, 1913	9.11	13.96
To H. C. Sampson, Chicago, addressing		1.85
To West Paper Co., Decatur, 400 printed postal cards		5.65
To O. W. Caldwell, Sec'y, telephone, stamps, drayage		4.50
To E. N. Transeau, Sec'y, freight and postage		3.02
To Charleston Courier, letter-heads, envelopes		8.00
Total expenditures		$68.16

SUMMARY

Total receipts, Feb. 22, 1913, to Feb. 20, 1914	$304.07
Total expenditures	68.16
Balance on hand Feb. 20, 1914	$235.91

J. C. Hessler, Treasurer.

REPORT OF THE COMMITTEE ON CONSERVATION

Your committee continued from 1913, appointed to confer with the railways of Illinois regarding the possibility of establishing plant reservations along the rights of way, begs leave to make final report as follows, and asks to be discharged from further efforts.

The Illinois Central Railway, as owner of the oldest established right of way in the state, was asked to join with the Academy in establishing 24 plant preserves of limited area in various counties from Jo Daviess to Alexander. If the railway company would abstain from mowing such preserves until after seeding time the Academy would properly placard them and interest local botanists in their continuance and upkeep. In this way many rare and rapidly vanishing prairie plants, such as Habenaria leucophoea, Liliums superbum and Philadelphicum, Ranunculus ovalis, Geum ciliatum, Acuan Illinoensis, Baptisia leucophoea, Psoralea tenuiflora, Amorpha canescens, Petalostemum candidum, Linum sulcatum, Polygala incarnata.

Violas pedatifida and pedata bicolor, Gaura biennis, Polytaenia nuttallii, Gentiana puberula, Asclepias sullivantii, A. rubra, A. verticillata, Phlox maculata, P. glaberrima, Liatris, Grindelia squarrosa, Echinacea purpurea and others might be saved.

The chief engineer of the railroad replied that the sections set apart would be untidy in appearance, occasion hazard from fire and endanger adjoining property, and if allowed to mature would go to seed and thus disseminate objectionable plants. He asked if the Academy would be willing to guarantee the railroad company against trouble by fire and would run plowed furrows around the areas planted at certain regular intervals. As the Academy would not undertake to carry out the propositions presented the matter was dropped.

H. S. Pepoon, Chairman.

REPORT OF THE COMMITTEE ON AN ECOLOGICAL SURVEY OF THE STATE

Your Committee on an Ecological Survey has to report that its work has been, during the past year, of substantially the same character as heretofore, the various members of the committee being severally engaged on their separate problems, co-operating by conference rather than by means of plans systematically co-ordinated in advance. Each of us is, in fact, so limited by location, official and educational engagements, and the like, that any more compact organization of our studies seems for the present impracticable. The ecologists of the Chicago area are, however, making steady and substantial progress towards a complete ecological survey of their territory. Elsewhere in the state our work has been virtually limited to the operations of the State Laboratory of Natural History together with the State Entomologist's office, the work of Doctor Adams's students at the University of Illinois, and the studies of Transeau and Hankinson at the Eastern Illinois State Normal School.

The most important items of progress during the year are three publications by members of the committee: Shelford's volume on animal communities in temperate America as illustrated in the Chicago region; Adams's guide to the study of animal ecology; and Forbes and Richardson's studies on the biology of the upper Illinois River, published as a bulletin of the Illinois State Laboratory of Natural History. The volumes by Shelford and Adams are invaluable to the student of ecology, supplying means of guidance, models of work, statements of principles, summaries of existing knowledge, and comprehensive references to literature, hitherto altogether wanting. Forbes and Richardson's work on the Illinois River has principal reference to pollutional effects and to fisheries, but takes into account the whole system of life from the microscopic plankton to the vertebrates, with only slight reference, however, to the larger plants. It represents the first attempt made in this country to correlate lists of biological species with degrees of contamination of the water, in a way to make the former an index to the latter. The paper has attracted the special attention of sanitary engineers. Besides the various ecological papers by Transeau, Hankinson, Harvey, and Fuller in the last volume of the Trasactions of the Academy, honorable mention should be made of a report on an Associational Study of Illinois Sand Prairies, by Arthur G. Vestal, which has been published, within the year, as a bulletin of the State Laboratory of Natural History.

The field work of the State Laboratory of Natural History has been devoted almost entirely to the Illinois River situation, in the form of a survey of the plant and animal life of the river and connected waters of the bottom-lands from Peoria to the mouth of the stream. The collections, mainly from the bottom and shores of the waters, were comprehensive of all animal forms except those of the plankton, and were made as nearly as practicable by quantitative methods, for the purpose of comparing the productivity of different waters and different parts of the stream system. Samples of the bottom sediments of the waters were systematically taken from a large variety of situations, and are now in process of analysis at the Chemical Laboratory of the University of Illinois. Regular series of water samples from various points down the river are also being obtained for analysis in the laboratories of the State Water Survey, the object of this study being to trace the transformations of sewage materials down the stream and to learn where they first become most available for the nutrition of plants and animals. Thorough statistical studies of the fisheries products of different sections of the Illinois River for a period of years have also been made, with some important economic consequences which will be presently detailed in a bulletin of the State Laboratory of Natural History, giving the product of the season's work.

Doctor Adams has completed his part of the report on the

Charleston survey, and this will presently be in press as a bulletin of the State Laboratory.

Doctor Shelford has made an extensive study of the behavior characters of an animal community inhabiting a swift stream. The results show that the various species of animals of this community are in agreement with respect to their reactions to current and bottom—that is, they select stones and avoid sand, and select strong current, placing themselves with their heads upstream. Their reactions to light and the positions they take up with reference to stones in the experiments, are in accord with their distribution in the rapids. The animals of a pool community, studied in a similar way, were found to give reactions decidedly different from those of the rapids community. Physiological responses are thus shown to be matters of the first importance in ecology.

Doctor Pepoon has accumulated further data in his study of the flora of the Chicago area, his list of which now numbers 1,800 species of the higher plants. He is studying the flora of the north shore as far as Waukegan, and Dr. Frank Gates has the Waukegan area itself. In connection with these studies, Prof. E. J. Hill is working upon the ecology of the Calumet-Des Plaines region, and Prof. L. M. Umbach on that of the DuPage valley area. It is hoped that the manuscript of this co-operative group may be ready for the printer by April 15. Doctor Pepoon has also begun an elaborate paper on the driftless area of Jo Daviess county, which will bring together all his materials concerning the plant problems of this peculiar region.

Mr. Baker is continuing his interesting studies comparing the remains of glacial life found in the deposits of Lake Chicago with the post-glacial plants and animals of the Great Lake region, with special reference to the origin of our present fauna and flora. These studies have extended to southwestern Michigan, where there are sedimentary deposits of the middle and later stages of the lake. Ancient marl beds in Pipestone Lake, Magician Lake, and in the old swamp near Buchanan have been examined, and their relation to the ancient Chicago outlet and to the old Kankakee outlet is now being worked out. Mr. Baker's work on Pleistocene life is now nearly completed, and embraces a list of all the plants and animals recorded from inter-glacial and post-glacial deposits of all the states surrounding the Great Lake region and southern Canada.

Doctor Cowles's personal work during the past year has lain outside the state, together with a large part of the work of his students. One of the latter, Mr. Ullrich, has maintained during the summer season a large number of atmometer stations for an extensive study of the moisture conditions of a ravine near Glencoe, Ill. Exact evaporation data were obtained for different situations in various parts of the ravine; and the soil moisture was determined weekly in a way to give the range of conditions throughout the season. The wilting co-efficient of the soils having been determined, the approximate amount of moisture available for plant growth was shown.

Mr. Hankinson is preparing for publication his data of the survey of the prairie and forest near Charleston, made in August, 1910, in co-operation with Adams and Transeau.

Doctor Transeau has continued his work on the periodicity of the occurrence and reproduction of the Algae. During the year past an attempt has been made to analyze the environmental factors related to these changes in the Algae. In addition to temperature records, the variations in the osmotic pressure of natural waters have been studied by means of the freezing-point method. These data have shown that, contrary to the accepted notion, when ponds and pools dry up in the summer, the concentration of the solution is not increased, but is usually greatly diminished. The highest concentrations occur during the periods of high water in spring, and during the early rainy period of autumn.

The evaporation rates and the soil moisture conditions in several of the forest-plant associations of the Chicago area. and in some bits of undisturbed prairie have been studied in a quantitative manner by Dr. Geo. D. Fuller and some of his students during the past four years. An attempt has been made, with considerable success, to relate these determinations to the succession of plant associations. These studies include areas at Miller, and Otis, Ind., Palos Park, and Chicago Lawn, Ill. A paper by Mr. J. F. Graves upon the present program gives some of the results of his studies in evaporation and soil moisture conditions in cultivated and natural areas. The data obtained during the years 1910-1913 have been collected by Dr. Fuller, and are now in manuscript and will be published at an early date.

We have finally to report action taken yesterday by your committee, looking to a program of correspondence and inquiry, and a search for relic situations characteristic of the more important ecological features of primitive Illinois. Such situations being found, fairly convenient of access from centers of investigation, it is believed by us that graduate students and others can be interested to study and report upon them, provided that some allowance of money can be made to cover the expense of the necessary travel; and some such co-operation the director of the State Laboratory of Natural History, who is also chairman of this committee, is prepared to offer us because of the importance of such studies as a contribution to the natural history survey of the state, in progress under his direction.

By the Committee:

Charles C. Adams,
Frank C. Baker,
Henry C. Cowles,
George D. Fuller,
Thomas L. Hankinson,
Hermann S. Pepoon,
Victor E. Shelford,
Edgar N. Transeau,
Stephen A. Forbes,
Chairman.

Evanston, Illinois, February 20, 1914.

THE PRESIDENT'S ADDRESS

Investigations of Mineral Resources and Industries of the United States

BY F. W. WOLF, DIRECTOR STATE GEOLOGICAL SURVEY

The importance of the United States as a producer and reserve supply of mineral for the World is not commonly realized. According to the latest available figures of the U. S. Geological survey, the country ranks first for eight minerals, and produces percentages of the world's output, (Figures 1 and 2) in each mineral, listed as follows:

Petroleum	64 percent
Smelted Copper	56 percent
Phosphate and Gypsum	50 percent
Iron	40 percent
Coal	38 percent
Lead	33 percent
Zinc	29 percent
Tungsten	28 percent

The history of mineral investigations and a review of their character will, I hope, be interesting to those Academy mem-

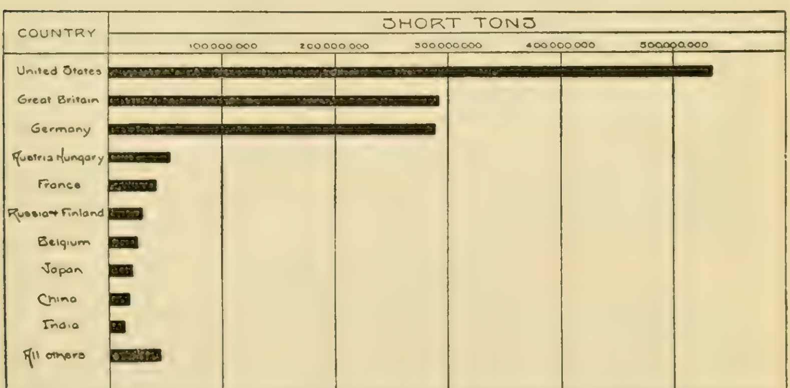


Figure 1. Production of Coal in Various Countries.

bers who are not themselves geologists or mining engineers. It is my plan to mention the important agencies engaged in investigation, and then to review the kind and scope of the various lines of work.

Among the important investigators may be mentioned those of the federal government, those of states, and those of private agencies.

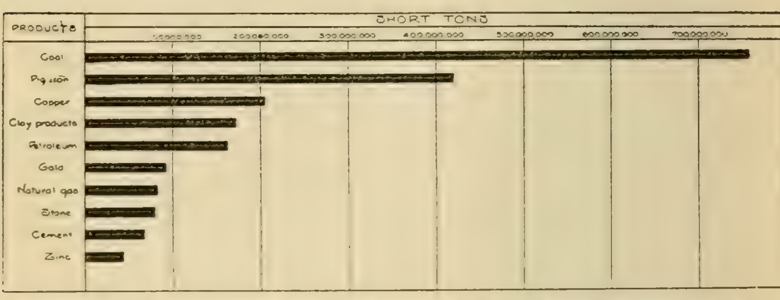


Figure 2. Relative value of United States Mineral Products.

FEDERAL BUREAUS

The U. S. Geological Survey was created in 1879 and has a record of service covering 34 years. During 1913 the work included geologic mapping in 45 states; topographic mapping in 26; stream gaging in 42; underground water studies in 19. Nearly 400 field men of the regular staff, besides numerous temporary assistants, were employed. The appropriations for the fiscal year exceed one and one-half million dollars.

As an off-shoot from the Geological Survey, the U. S. Bureau of Mines was created in 1910 to conduct investigations into safety and efficiency of the mineral industry. More than 150 technical men were employed in 1913. The Bureau maintained offices or laboratories in three cities outside Washington and operated six mine-safety stations and seven mine-rescue cars.

Another governmental office, the Bureau of Standards, conducts tests of clay and concrete materials, and investigates the use of electricity and other substances in mining.

STATE AGENCIES

Among the state agencies of mineral research should be mentioned first the geological surveys. Many of them came into existence between 1830 and 1840, and most of them have enjoyed long, though intermittent periods of usefulness. The present surveys range in age from 6 to 50 years and average

18 years. Three have existed more than 40 years, two others more than 30, and five others more than 20 years. The thirty-five state surveys were especially active during 1913, collecting and disseminating information intended to promote the orderly development of mineral resources. Several surveys also had responsibility in connection with highways, soils, forests, and reclamation of wet lands. Besides having these utilitarian functions, the surveys contributed notably to pure science. Altogether the state surveys expended approximately $475,000, and received the benefits of $140,000 additional expenditure by co-operating federal bureaus. About 100 scientists gave full-time service for the states, and about 50 others, besides topographers and soil experts, were furnished in co-operation.

To enumerate the mining schools or departments, and the experiment stations of the country would almost require a roll-call of States. But among the notable contributors to the profession may be mentioned Columbia, Yale, Michigan, Colorado, Minnesota, Missouri, and our new school at Illinois. These, together with the geological and chemical departments of our universities are producing the graduates who influence the mineral industry. The field and laboratory researches of these schools and colleges include real contributions to practical knowledge.

PRIVATE AGENCIES

Aside from official surveys, bureaus and educational institutions already presented, there are many private agencies of research and publication. An important work is done by professional and practical men who publish the accounts of their work in the dozen or more technical papers of the country. Mention should be made also of the research by great corporations which annually explore and drill mineral land. They either follow-up and utilize the results of official field work, or take the initiative themselves. The spectacular but fundamental work of the Carnegie geophysical laboratory has a practical bearing on problems of mineralization. Finally, a necessary forum of the mining business is provided by the American Institute of Mining Engineers, the American Mining Congress, and related organizations.

CHARACTER OF INVESTIGATIONS

A review of the character of investigations of mineral resources and industries includes, first, the early frontier explorations, then modern work. In this latter division are included topographic mapping, general geologic surveys, land classification, economic studies of particular minerals or substances, and technologic investigations.

The frontier explorations are described by Merrill,* from whom I quote freely.

The era of state surveys begins with the decade 1830-1839. During this interval scarcely a year passed but witnessed the establishment of a state survey or the organization of an exploring expedition, to which a geologist was attached. Thus were established surveys in Massachuetts in 1830; in Tennessee in 1831, Maryland in 1834, New Jersey, Connecticut and Virginia in 1835, Maine, New York, Ohio and Pennsylvania in 1836, Delaware, Indiana and Michigan in 1837, and in New Hampshire and Rhode Island in 1839. In addition, the United States Government for the first time recognized the practical utility of the geologist by authorizing the surveys by G. W. Featherstonhaugh of the elevated country between the Missouri and Red Rivers in 1834, and of the Coteau des Prairies in 1835; and by D. D. Owen of the mineral lands of Iowa, Wisconsin, and Illinois in 1839.

The fever for the state surveys, so prevalent during the first decade, seems to have quickly subsided, since during the following period, new surveys were established only in Alabama, South Carolina, and Vermont. Governmental surveys were also few, being limited to those by D. D. Owen in the Chippewa land district, and Jackson, Foster and Whitney in the Lake Superior region.

The cause of this sudden cessation is not quite apparent. It is possible, that the period of great financial depression beginning in 1836 may have had something to do with it. An important factor may have been the lack of geologists to agitate the subject and carry on the work, since nearly every man of prominence and experience was engaged in surveys and organizations already under way. The period was one of importance for results rather than for organization and preparation.

The single event of greatest consequence during this second decade was the appearance of the final reports of the New York survey. The volume of literature was naturally greater than at any previous period, since it included many of the reports of organizations of the previous decade, as those of Percival in

*Geo. P. Merrill, Contributions to history of American Geology; Annual report, Smithsonian Inst. 1904.

Connecticut, Booth in Delaware, Jackson in New Hampshire and Rhode Island, and Rogers in New Jersey. The establishment of a geological survey of Canada in 1841 should also be mentioned.

The financial depression, which proved so fatal to the state surveys during the second decade, 1840-1849, ran its course. Several new states had in the meantime been added to the Union, some of which showed commendable promptness in authorizing geological surveys. During the decade 1850-1859 new organizations were thus formed in fourteen states, eight of which had made no previous attempt. These eight, in alphabetical order, are California, Illinois, Iowa, Kentucky, Mississippi, Missouri, Texas, and Wisconsin. Six states for the second time undertook the work—Michigan, New Jersey, North and South Carolina, Tennessee, and Vermont. The National Government was also active, the most importat undertaking being the surveys in connection with the proposed Pacific railways. In addition to these, Capt. R. B. Marcy made a survey of the Red River region of Louisiana; Maj. W. H. Emroy, one of the Mexican boundary, and Colonel Pope one in the region of New Mexico along the thirty-second parallel. To each and all of these expeditions, geologists, or at least naturalists, were attached. The publication of by far the greatest importance of this third decade was, however, the long-delayed report of the Pennsylvania survey, which was truly epoch-making.

The following period, including the civil war, might naturally be expected to be one of uncertainty and inaction in matters relating to the sciences. With the passing of the war, active work has begun once more in states where it had been but temporarily suspended, and in others, new organizations were authorized, as in Kansas in 1864, Iowa and North Carolina in 1866, and Louisiana, Michigan, and Ohio in 1869.

The decade of the civil war brought to light a number of men for whom the piping times of peace, even when varied by Indian outbreaks in the West, afforded insufficient opportunities. They were men in whom the times had developed a power of organization and command. They were, moreover, men of courage to the point of daring. It was but natural, therefore, particularly when the necessity for military routes in the west and public land questions were taken into consideration, that such should turn their attention toward western exploration. Further, the surveys made in the third decade, in connection with routes for the Pacific railroads, and the work done by Evans, Hayden and Meek in the Bad Lands of the Missouri, had whetted the desires of numerous investigators. Willing workers were abundant during the fourth decade, 1870-79, and Congress not difficult to persuade into granting the necessary funds. Hence expedition after expedition was organized and sent out, some purely military, some military and geographic, with geology only incidental, and others for the avowed purpose of geological research.

Under such conditions was inaugurated the work which culminated, in 1879, in the organization of the present U. S. Geological Survey, which, for breadth of scope and financial resources, is without counterpart in the world's history of science.

The more important of the expeditions above referred to were Hayden's Geological Surveys of the Territories; King's Geological Survey of the Fortieth Parallel; Powell's Surveys of the Grand Canyon of the Colorado and adjacent regions; and Wheeler's Geographical Surveys West of the One-hundredth Meridian.

It is possible only to mention the organizations of these four decades and it is necessary to omit the results of the work, except to say that the knowledge of the mineral resources of the States and territories was extended rapidly and made a matter of public record by the frontier explorations. Much of the work of the early 50's was wonderfully well done.

LATER INVESTIGATIONS

Topographic mapping is of great value as a basis for study of mineral resources. While at least three states have made such surveys systematically, the U.S. Geological Survey has executed nearly all topographical surveys now available to the public. The total surveyed to date equals 40 per cent of the country. In this work about twenty states co-operate and furnish half of the necessary funds. Practically $600,000 was spent for public topographic surveys in the United States during the fiscal year 1913. More than 22,500 sq. mi. (one half of Illinois) was actually surveyed. The total surveyed to date equals 40 per cent of the country.

General geological surveys of specific areas have been the approved type for public and corporation work, and maps, (Figure 3) and reports based on states, counties, quadrangles, or other units have aimed to portray the kinds and relations of all the exposed formations and to present the facts relating

Figure 3. Distribution of Petroleum and Natural Gas Fields in the United States. After Day, U. S. Geological Survey.

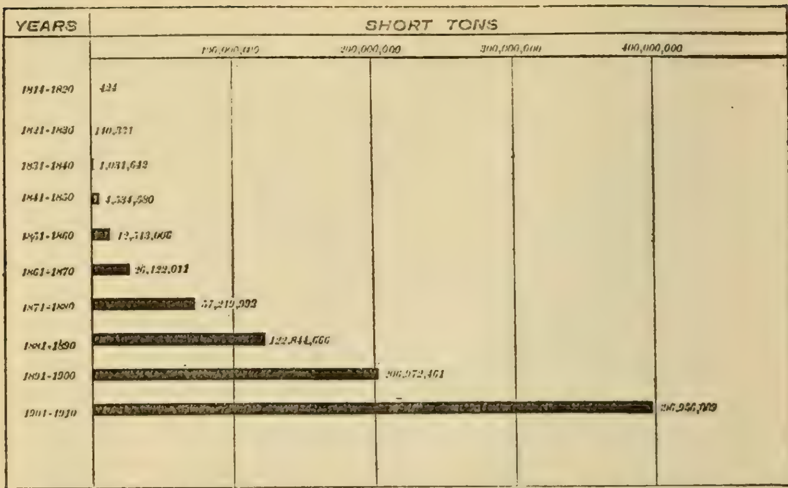


Figure 4. Average yearly production of Coal in decades for the United States.

to all mineral resources, including soils and waters. This is perhaps logical in frontier areas of slight development.

Most of the states have been mapped, at least in reconnaissance by local bureaus, though detailed work after modern standards has been completed only for states of small area, or for small fractions of the larger states. The U. S. Geological Survey work has spread over much of the country as shown by figure 4.

Classification of public land by the U. S. Geological Survey has become an important division of work. The purpose is to determine whether certain lands sought to be acquired from the Government are of the character contemplated by the statute under which they are sought. Large withdrawals from entry of public lands during several years, have been made by the President or by the General Land Office, pending classification of the land as to its mineral character.

The Land Classification Board of the Survey, comprises eleven geologists and engineers, and twenty-three others of minor grade. The work is done by sections devoted to the following subjects: Coal, oil, phosphate, metallic ores, water power and irrigation. The basis of classification and valuation of coal land is logical and depends chiefly on the thickness, depth, and heat value of the coal. Phosphate beds containing less than 30 per cent of tricalcium phosphate are considered to be non-mineral. Beds containing 70 per cent or more, and measuring 6 feet or more in thickness, are reserved to a depth of 5,000 feet. Intermediate grades are reserved to lesser depths.

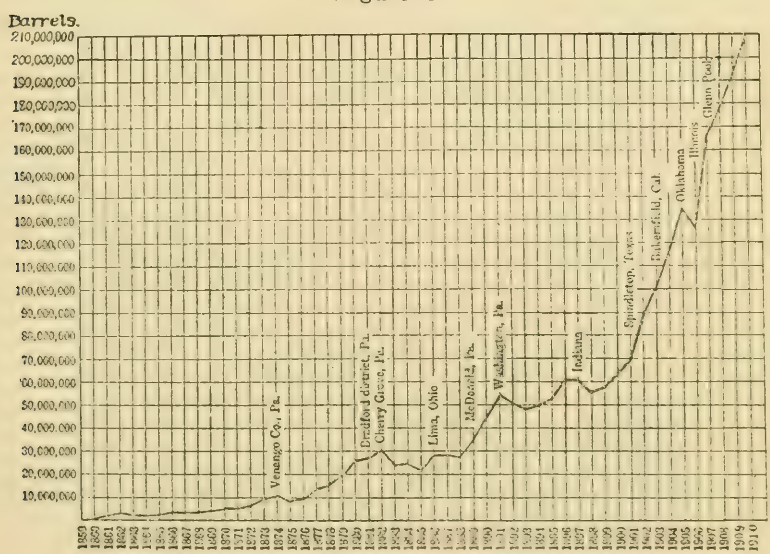
During 1913, more than 2,000,000 acres of coal land were classified, and valued at nearly 33½ million dollars, while nearly 8,000,000 acres were classified as non-coal land. To date the classifications include 19,000,000 acres of coal land, 61,000,000 non-coal land. There is awaiting classification the following lands, expressed in acres:

Coal—58,000,000; oil 4,600,000; phosphate, 3,000,000; potash, 130,000.

Besides this federal classification work several states, notably Michigan, Minnesota and Wisconsin, delegate similar work to their geological surveys in co-operation with their tax commissions. All mineral lands are to be classified as a basis for taxation. In Wisconsin, during 1913, nine field parties were engaged in making magnetic surveys to determine the iron-bearing lands not yet under development.

Recently investigations of particular minerals or substances are perhaps occupying a more important position than general areal surveys. Reports on coal, oil, iron, clay, phosphate, platinum, etc., of various states or smaller areas, have been issued by public or private investigators and have been of great practical use to the mineral industries. Numerous specialists in particular lines of work have developed and have largely superseded the general geologist and mining engineer of all-around work. This has come about largely because of the increased utilitarian functions of the work, but even in its pure-science aspects a high degree of specialization has evolved. The distribution of important resources is shown by figures 5 and 6.

Figure 5



ANNUAL PRODUCTION OF PETROLEUM, 1859 TO 1910.

Figure 6. Distribution of Coal Fields in the United States. After Campbell and Parker, United States Geological Survey.

The statistical work of the U. S. Geological Survey is carried on under the direction of twenty or more geologists who have become expert in regard to special mineral industries. Over 62,000 operators report annually the details of their production, but this report is supplemented by personal visits of experts to significant operations in all mineral lines.

Specialization in study of water resources is now common throughout the country. The U. S. Geological Survey maintains twelve district offices in the country and records the stream measurements from over 1100 stations. It also has experts in underground-water studies. A series of reports on this subject for the entire coastal-plain region of the Atlantic and Gulf states has been completed.

Among the subjects covered by the state surveys from year to year may be mentioned those of the 1913 program, as typical. Reports were issued by various states on: Building stone, cement materials, agricultural limestone and marl; stone and gravel for highways, concrete and ballast; clay, shale and fire-clay; asbestos, soapstone, feldspar; salt, gypsum, glass-sand, lithia, rock-phosphate; coal, lignite, peat, petroleum, gas; precious metals, iron, lead, zinc, copper; underground and surface waters.

TECHNOLOGIC STUDIES

Finally a view of investigations of the mineral industries would be incomplete without consideration of *technologic studies*. These are doubtless in progress in innumerable lines by chemists, metallurgists, and engineers employed by corporations and other interests, and the resulting increased efficiency in recovery and utilization of mineral products, and in safety of employes is truly remarkable. Among the lines of public investigation and experiment by the U. S. Bureau of Mines, by various mining schools, and by the state surveys should be mentioned the following:

Increased safety and efficiency in mine timbering, ventilation, hoisting, and in use of explosives and electricity; elimination of explosions due to gas and to coal dust; perfection of processes for by-product coking, briquetting, and for gas-producer operation; recovery of low-grade ores and of colloidal slimes, and other milling wastes; smelting of refractory ores and recovery of waste gases; practical tests of clay materials for extended uses; checking wastes of natural gas and extending the life of oil fields by preventing refrigeration and precipitation in the sands, and by controlling movements of water in the sands.

Truly, the investigation of the mineral resources and industry of the country covers a magnificent field of the highest importance to the nation's life and prosperity. Considering the brief span of years already employed, the knowledge of distribution, character, and utilization of our mineral wealth is surprising. Furthermore, when it is remembered that the most rapid contributions to knowledge and most extensive development in operations have come during the last fifty or even thirty years, the promise for increased efficiency and scientific development and management in the near future is exceedingly bright.

RIGIDITY AND VISCOSITY OF THE EARTH, AND THE BEHAVIOR OF SUBSTANCES UNDER STRESS

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The experiments recently conducted at the Yerkes Observatory for the purpose of ascertaining the action of the mass of the earth in yielding to the gravitation forces of the sun and the moon, gave the result that the earth acts like a solid body with an elastic coefficient of the order of that of steel—and with a coefficient of viscosity which is very high—probably also of the same order as that of steel.

For detailed account of these experiments, see Journal of Geology, Vol. XXII, No. 2, 1914.

From the known increase of temperature as we go below the surface of the earth, it follows that the temperature of the interior must be very high—high enough to melt almost if not quite all known substances under normal conditions.

It follows that the enormous gravitational pressure which the mass of the earth experiences is sufficient to prevent this fluid condition—in other words, that pressure increases elastic rigidity as well as viscosity.

An attempt was made to detect such an effect, using the relatively small pressures obtainable in the laboratory (of the order of 50,000 pounds per square inch) and the results obtained clearly confirmed this conclusion. However, certain rather curious and baffling anomalies presented themselves which made the results less conclusive than was anticipated.

The study of these anomalies has been in progress for several months and an account of the results will probably be published as soon as the information obtained is available.

At present it may be stated provisionally that the laws governing the behavior of substances under stress are the following:

First—There is a rapid elastic yield, which, if inertia be negligible, is practically instantaneous.

Second—This is followed by a slower yielding which diminishes with the time and ultimately attains a constant value which may be zero.

Third—If the stress is released the specimen returns almost instantly to a point short of its original position.

Fifth—The behavior depends, in many cases, on the previous stresses to which the specimen has been subjected—these usually tending to strengthen the specimen.

These experimental results are to be accounted for on theoretical grounds and considerable progress has been made in this direction.

THE INTERNATIONAL PHYTOGEOGRAPHICAL EXCURSION

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In the summer of 1911, there was organized in the British Isles under the auspices of the British botanists, the first International Phytogeographical Excursion. This was so successful in getting plant geographers from various countries together for the purpose of discussion in the field that it was unanimously decided to have a similar excursion in the United States in 1913. The 1913 excursion started at New York on July 26th, and closed at the same city on October 5th. The general route of the excursion included the following places: Niagara Falls, Chicago and the neighboring sand dunes; Lincoln, Akron, Colorado, Colorado Springs, Pikes Peak, Salt Lake City, North Yakima, Tacoma, Mt. Rainier, Crater Lake, San Francisco, Mt. Tamalpais, Yosemite, Carmel and Cypress Point, Salton Sea, Tucson, the Santa Catalina mountains, and New Orleans.

The excursion numbered from twelve to fifty, depending upon the number of American participants at various places. Ten European members were present at most all of the points visited. Among others, these Europeans included such well-known plant geographers as Professor Engler of Berlin; Professor Schroter of Zurich, and Mr. Tansley of Cambridge. Professor von Tubeuf, the famous student of trees and their diseases, was also a member of the party.

Nearly all of the great American types of vegetation were visited and studied, numerous photographs being taken and numerous plant specimens being collected. Professor Henry C. Cowles of the University of Chicago had general charge of the excursion, but was ably assisted by Professor Frederick E. Clements of the University of Minnesota; Dr. George E. Nichols of Yale University, Dr. George D. Fuller of the University of Chicago, and Dr. Alfred Dachnowski of Ohio State University, as well as by large numbers of botanists at the places visited.

RECENT THEORIES OF FERTILIZATION AND PARTHENOGENESIS

BY FRANK R. LILLIE, UNIVERSITY OF CHICAGO

Two main problems of fertilization stand in the foreground of all recent work viz: the problem of the initiation of development and the problem of bi-parental inheritance. The latter problem has received a much more complete and satisfactory analysis than the former which is alone under consideration in the present paper. The problem may be stated thus: Why is the unfertilized egg usually incapable of development? And how does the spermatozoon initiate the developmental processes?

This problem was naturally conceived in the early part of the modern period (1875 to the present) in morphological terms; and Boveri's theory that the egg did not develop because it lacked the "organ of cell-division" (viz: the centrosome) and that the spermatozoon enabled it to develop by supplying the missing organ was long held by most naturalists. But with the advent of physiological analysis of cell life the inadequacy of this point of view soon made itself felt. The discovery of artificial parthenogenesis by Loeb started a new era in this problem. It was shown that the role of the spermatozoon could be dispensed with in initiation of development, and that a change in the chemical constitution of the medium could take its place. In such a case it was obvious that no new cell organ was needed by the egg. Following this epoch-making discovery a great many investigators studied the problem of initiation of development in the eggs of various species of animals, with the result that a great variety of agents was shown to be effective in the production of parthenogenesis in different forms. These can be classified under the head of chemical agents, osmotic changes, temperature changes, radiation, mechanical shock and pricking. In fact a very considerable proportion of the agents effective in stimulating protoplasm may be efficient agents in inciting parthenogenesis in one or another variety of eggs. It has been argued that, if it were possible to find the common factor of all efficient parthenogenetic agents, the cause of the initiation of development would be found. This attempt has not, however, led to a satisfactory explanation; and it may be doubted whether such a form of analysis would lead to any more satisfactory results in the case of initiation of development than in the initiation and propagation of a nerve impulse, which may be equally well started by a similar set of external changes.

Moreover, while it is obvious that in parthenogenesis, part of mechanism of fertilization must be employed, we need not necessarily gain any direct knowledge of the true fertilization reaction between ovum and spermatozoon. In fact if we were to accept any theory of parthenogenesis we would still be far from understanding many of the phenomena of fertilization associated with initiation of development.

On any such basis (1) We do not understand the nature of the immediate reaction between the ovum and spermatozoon in fertilization; (2) We do not understand the nature of the reaction of the sperm nucleus in the interior of the ovum; (3) We do not understand why fertilized ova become non-fertilizable; (4) Why immature ova are non-fertilizable; (5) We do not understand the variations of affinity within a species, leading to almost absolute sterility in self-fertilization in some cases, or between the members of certain varieties in other cases; (6) We do not understand either the sterility or fertility of different species when bred together.

Not only are these unsolved problems, but we have only the slightest experimental basis for their solution by methods of parthenogenesis. A vague conception that the solution of such problems must lie in the field of chemistry has been entertained, but without any experimental basis whatever until very recently, and that of a slight character.

If these things are true the defect must lie in the methods of investigation because some of the most brilliant students of biology have been concerned with the problems of fertilization. The defect in the methods of artificial parthenogenesis is obvious, because it consciously restricts the field of investigation. Nothing less than an analysis of the process of fertilization itself can give a rounded theory of fertilization. The study of merogeny, of hybrid fertilization, of partial fertilization, of self-fertilization, of the antagonistic action of sperm suspensions of different phyla, of the fertilizing effect of injured spermatozoa, etc., are methods that have recently been employed for the direct analysis of fertilization, and which have aided greatly in the definition of problems, though but little in their solution.

I have therefore attempted for some years to make a direct analysis of the fertilization problem, and have developed two new methods of analysis: (1) The use of sperm-suspensions as indicators of reactions. (2) The study of fertilization by inhibitors.

The first method was suggested by the fact that many of the most delicate of biological reactions are determined by the use of living cells as indicators. In the field of immunology no other indicators are known for bodies concerned in such reactions in many cases. The sperm cells of a species might be expected to serve as indicator of substances formed by the egg with which reaction normally takes place in fertilization. As regards the second method, it is obvious that an analysis of the reaction concerned in fertilization might be attempted by agents which would hinder the normal course of events at any place. This would constitute a method of analysis by which the total reaction might be broken up into its elements.

I. *Results from the Use of the Sperm Suspensions as Indicators.*

If some of the sea-water from a suspension of eggs of Arbacia be added to a milky suspension of the sperm of the same species in sea-water, a very rapid agglutination is obvious to the naked eye, resulting in the formation of detached white masses of agglutinated spermatozoa, leaving the fluid more or less clear, depending on the strength of the reaction, In a few minutes the agglutinated masses break up into their constituent elements and the suspension becomes milky again. The reaction cannot be repeated in the case of the sperm suspension, if it is incomplete in the first instance. In chemical terms it cannot be repeated after saturation. The spermatozoa, however, retain their vitality. We have then a combination of some elements of the spermatozoa with a secretion from the ripe ova, which so alters the physical character of the sperm cells that they adhere in masses. The reaction in question is without prejudice to the life of the spermatozoa.

The agglutinating substance is produced only by ripe eggs of Arbacia, and not by immature eggs or by any other tissue of the species; in other words, only fertilizable eggs produce it.

The substance is more of less specific in as much as it will not agglutinate the spermatozoa of Nereis for instance. Professor Loeb has since been able to determine a higher degree of specificity, as between related species of sea-urchins

It is possible to study the production of this substance quantitatively, that is to say, a given bulk of ripe eggs may be shown to charge a given amount of sea-water to an extent that may be measured in the following way: The agglutination as noted, is reversible. It is therefore possible to establish a minimum reaction as unit in which reversal takes place in four to five seconds. Then the amount of dilution of a given agglutinating solution necessary to reduce it to unit strength is a measure of concentration of the agglutinating substance.

To give an idea of the quantities involved it may be stated that sea-water which has stood over one quarter its bulk of ripe eggs for half an hour may be capable of 1/800 to 1/3200 dilution, or is of the strength of 800 to 3200 agglutinating units. By another method we may ascertain that a single c.c. of the eggs placed in 8000 c.c. of sea-water will charge the whole body of sea-water with sufficient quantity of the agglutinating substance to be detected. The unfertilized ripe eggs of Arbacia produce this substance as long as they live and remain in a fertilizable condition; they may be washed repeatedly in sea-water, and when restored to fresh sea-water this is soon found to be charged with the substance in question. In certain experiments I have carried out thirty-five successive washings of a given lot of eggs during a period of three days without being able entirely to dispose of the agglutinating substance.

Definite quantitive relations in the reaction with the sperm suspension may also be estimated by the number of units of the agglutinating substance which can be neutralized by a given standard suspension of the spermatozoa. For the details, I must refer to previous papers.

On account of the activity of the eggs in producing this substance and the avidity of the sperm for it, it seems reasonable to assume that it plays some part in the normal fertilization reaction.

It was therefore interesting to find that the eggs contain a substance, which they do not normally secrete, which neutralizes the sperm-agglutinating action of the egg-secretion,

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*These observations must be made under the microscope: a quantity of sperm suspension is mounted on a slide under a raised cover slip, and a drop of the fluid to be tested is injected into the suspension by means of a capillary pipette.

i. e., which renders the combination of the sperm with the agglutinating substance impossible. The presence of this substance may be demonstrated by methods that plasmolyze the egg or extract its internal substances. If for instance, eggs are deprived of the jelly in which they are normally embedded, and which is heavily charged with agglutinating substance, in order to get rid of excess of the agglutinating substance, and are then divided into two equal lots, one of which is placed in a certain quantity of sea-water, and the other in an equal bulk of distilled water, it is found that plasmolysis takes place in the distilled water, and internal substances are extracted from the egg. The supernatant fluid from the distilled water is at first more highly agglutinative than the sea-water, which contains only the normal secretion of the eggs. But there is present in the distilled water extract, a substance which tends to inhibit agglutination, and in a short period of time distilled water extract becomes entirely neutral. This is not merely an effect of distilled water on the agglutinating substance, because the latter may be kept for a long period of time in distilled water without deteriorating, but it is due to the presence of a body which actually destroys the agglutinating substance, or combines with it, in such a way as to prevent its effect.

These results suggest that in normal fertilization the combination between the agglutinating substance and the spermatozoon is essential, and that polyspermy is prevented by a neutralization reaction between the two substances produced by the eggs. I have therefore proposed the term *fertilizin* for the sperm agglutinating substance, and *anti-fertilizin* for the other.

It would follow that eggs in which the fertilizin is removed by any method should be incapable of fertilization. While it has proved extremely difficult to completely dispose of the fertilizin content of eggs, and to test this conclusion, it has nevertheless been possible by repeated washings greatly to reduce the fertilization content of eggs and secure the demonstration that the capacity for fertilization is correspondingly reduced.

Eggs when once fertilized are incapable of fertilization, that is to say the protoplasm of such eggs will no longer react with the spermatozoa. Such eggs should therefore *ex-hypothese,* be devoid of fertilizin content and this is the case.

To sum up: It is shown that ripe unfertilized eggs of Arbacia secrete a substance which produces a more or less specific agglutination reaction with sperm of the same species. Before acquiring this substance, *i. e.,* before ripening, the eggs are incapable of fertilization; after it is lost, whether by washing or preceding fertilization, the capacity for fertilization is also lost. We therefore conclude that the agglutinating substance is necessary to fertilization.

II. *Use of Inhibitors.*

1. Inhibitors in blood.

It is a fact well known to Embryologists, but hitherto not studied in any systematic fashion, that the plasma of blood or tissue secretions of the species tends to hinder the fertilization reaction.

I have made a somewhat detailed study of this phenomenon in the case of the Sea-Urchin, Arbacia punctulata, the detailed results of which are published in volume 16, of the Journal of Experimental Zoology. Here it may suffice to say that the addition of filtered serum of Arbacia blood to the sea-water in which insemination is to be performed, strongly inhibits fertilization. If a series of blood solutions containing, let us say 10, 20, 30, 40 per cent, etc., up to 100 per cent blood be prepared and equal quantities of ova inseminated with equal quantities of spermatozoa in each member of the series, the per cent of fertilization will usually run from about 100 per cent in fertilization control to zero in the undiluted blood serum. All the sperm are living and active in each member of the series.

The inhibition by the blood is not due to direct harmful action on either reproductive element alone for either eggs or spermatozoa may be exposed to the action of such solutions and after washing be found to possess good capacity for fertilization. It might be supposed that the inhibitor acts like the anti-fertilizin by preventing union between fertilizin and spermatozoa. This is, however, not the case because of a solution of fertilizin in blood is as effective in agglutinating spermatozoa as a similar solution in sea-water.

A second hypothesis would be that the inhibitor might act on a second side-chain of the fertilizin which is active in fertilization by combining with certain constituents of the ovum. If this is the case it would follow that the inhibitor in the blood could be neutralized by first saturating it with fertilizin from other eggs and this is found to be the case: If a given sample of blood be divided into equal parts of which one is saturated by fertilizin from unfertilized eggs, and inseminations be made in graded series of both, the usual inhibition reaction will be found in the first series, but is entirely absent in the second series.

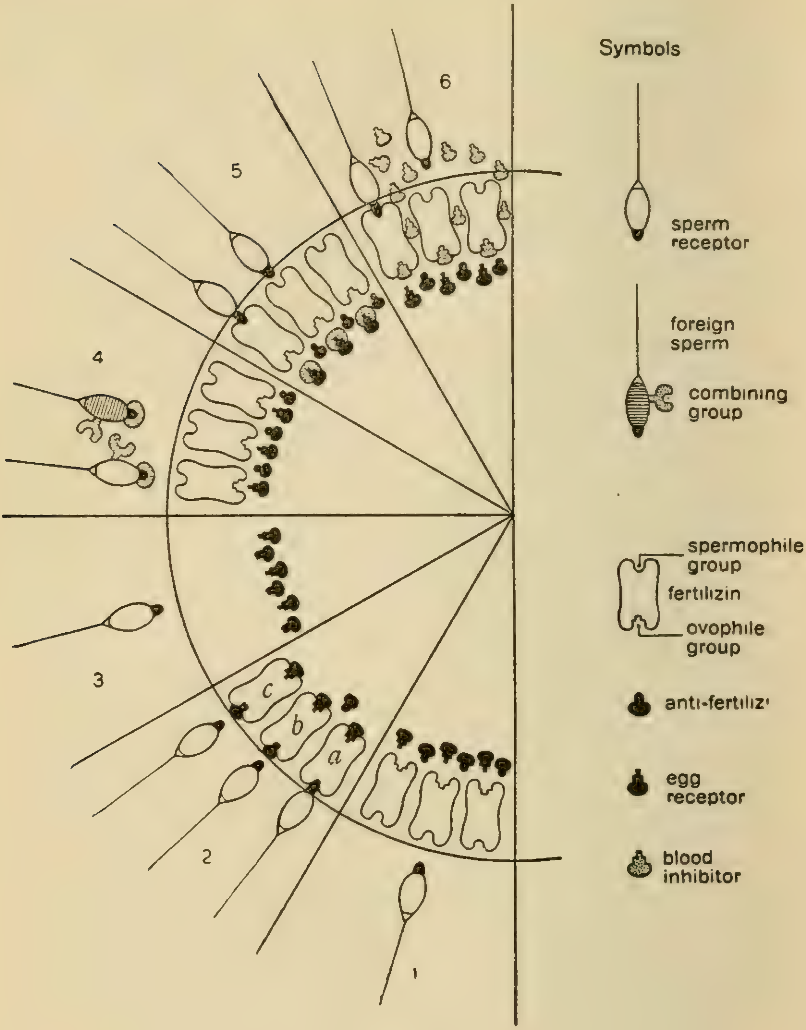

Figure I

DESCRIPTION OF FIGURE

Fig. 1. In successive sectors of the egg there are represented the mechanism of fertilization and the blocks to the mechanism, as follows:

Sector 1. The arrangement of substances in the unfertilized egg and in the spermatozoon that are active in fertilization. See explanation of symbols.

Sector 2. The mechanism of normal fertilization. The sperm receptor unites with the spermophile group of the fertilizin and the egg-receptors with the ovophile group of the fertilizin owing to activation of the latter by the sperm (a). Molecules of the anti-fertilizin combine with the spermophile group of the adjacent fertilizin (b and c) and thus block the way for supernumerary spermatozoa. This is the postulated mechanism for prevention of polyspermy. At the same time molecules b and c of the fertilizin have also united with the egg receptors.

Sector 3. Inhibition of fertilization by loss of the active body, fertilizin.

Sector 4. Theory of antagonistic action of spermatozoa of different phyla. The sperm receptors are occupied by combining groups cast off by the antagonistic spermatozoa.

Sector 5. Fertilization is blocked by occupancy of the egg-receptors. Purely hypothetical.

Sector 6. Theory of inhibitory action of blood of the same species. The ovophile group of the fertilizin is occupied by molecule in the blood (inhibitor) possessing the same combining group as the egg receptors. Molecules of the blood inhibitor also shown in the medium.

The fertilizin is represented in the diagram as occurring only in the cortex of the egg. But it also occurs in high concentration in the jelly surrounding the egg. The spermatozoon must thus normally arrive at the egg-membrane loaded with combined fertilizin. This fact, however, makes no essential difference in the theory, and its representation would complicate the diagram.

We therefore came to the conclusion that the substance which we have been calling fertilizin is the active agent in fertilization. That it possesses two side chains, one of which is spermophile, combining with certain elements of the spermatozoon (sperm receptors), the other of which (the ovophile) combines with certain elements in the egg (egg receptors). Fertilization is therefore not a two-body but a three-body reaction. Of these one is carried by the spermatozoon, the sperm receptors, and one by the egg, the egg receptors. The third, (fertilizin) is produced by the egg and reacts with both the others. The essential reaction in fertilization must be regarded as that of the fertilizin with the egg receptors; and the spermatozoon must be regarded as playing the secondary role of activator. In parthenogenesis the active body is still the fertilizin, and the various parthenogenetic agents, in this case play the role of activators. Thus parthenogenesis and fertilization may be regarded under one point of view.

The diagram represents the foregoing theory with the aid of symbols. Sector one illustrates the relation of the side chains before fertilization. Sector two illustrates normal fertilization. Some of the consequences of the theory are indicated as follows:

1. (Sector 3). If the egg loses its fertilizin it cannot be fertilized. This we have already seen.

2. (Sector 4). If the sperm-receptors are occupied, the spermatozoa cannot fertilize. The *Godlewski phenemenon* (Antagonism of sperm suspensions.)

3. (Sector 5). If the egg receptors are occupied, fertilization cannot take place. *Purely Hypothetical.*

4. (Sector 6). If the ovophile side-chain of the fertilizin be occupied, fertilization cannot take place. *Inhibiting action of blood.*

5. (Sector 2, b and c). If the spermophile side-chain be occupied, fertilization cannot take place. *Action of anti-fertilizin; prevention of polyspermy.*

It is obvious that these five blocks are purely chemical in their conception, but the possibility of other blocks in the fertilization reaction must not only be conceded, but strongly emphasized; as the essential reaction takes place across the egg membrane, the condition of this membrane, whether permeable or impermeable, is an essential factor in the reaction. The reaction must also be subject to the usual environmental conditions of comparable bio-chemic phenomena, such as temperature, ionic constitution of the medium, etc. Modification of these conditions will determine the occurence or non-occurrence of the fertilization reaction.

This theory transfers the fertilizing power from some hypothetical substance contained in the spermatozoon to a definite substance contained in the egg itself, in relation to which the sperm acts merely as an activator. It is therefore radically opposed to the theory that the sperm carries a lysin or other substance that acts directly on the cortical layer of the egg.

The mechanism which we have been considering concerns the cortical changes in the egg. The question therefore arises, whether the second phase of fertilization which I have shown previously to be dependent on the penetration of the spermatozoon, is likewise a three-body reaction, and if so whether the fertilizin is the intermediate body in this case also? This is a problem that I have not yet fully worked out, but the indications are for a positive answer to both these questions. There are a number of facts of considerable interest in this connection. (1) As is well known for Arbacia, spermatozoa may penetrate ovocytes but without fertilizing them; In Chaetopterus I have observed the same fact. (2) If the cortical changes are induced mechanically or chemically in the egg of Nereis, there is a stage where the spermatozoa may still penetrate but without causing complete fertilization. Miss Allyn demonstrated the same facts for Chaetopterus. (3) Dr. Kite observed that the injection of from 3 to 20 spermatozoa into the interior of the egg of Asterias with a microscopic capillary pipette does not result in any fertilization reaction. These facts indicate that when spermatozoa penetrate before the formation of fertilizin (ovocytes) or after its fixation (Nereis and Chaetopterus), or without the opportunity of reacting with the fertilizin (Dr. Kite's experiment) fertilization fails.

In these experiments we have egg and sperm in most intimate relations, but apparently incapable of reacting in the absence of an intermediate body, which appears to be the same body, viz: the fertilizin, through the mediation of which the cortical changes are induced.

In serum physiology, we have become familiar with many reactions for which living cells alone are adequate indicators; such are agglutination, cytolysis, opsonic reactions and anaphylaxis; the bodies concerned in such reactions viz: agglutinins, cytolysins, opsonins, etc., are not known directly, but only by the use of cell indicators. Their chemical nature is entirely unknown, but they are so definitely known through cell indicators, and so controlable, that many quantitative procedures of the most delicate character, in immunology, are based on this knowledge. The cells themselves are the source of such bodies, yet the site of their cellular origin is unknown, and their roles in normal cell physiology are problematical.

The ordinary chemical analysis of the cell begins by destruction of its more highly organized living constituents; it is obvious that such methods are inadequate for the investigation of the immediate reactions in living protoplasm.

The results of these experiments may then gain a still broader interest if they be taken to indicate a method for the study of such reactions.

THE MOVEMENT TOWARD A UNIFIED SCIENCE COURSE IN SECONDARY SCHOOLS

BY HAROLD B. SHINN, CARL SCHURZ HIGH SCHOOL, CHICAGO

The title of this report, as announced, is the result of careful editorial work on some one's part and we would correct it immediately. It would appear that there can be no real "Unified Science Course" as long as localities and their needs are different, or as long as men's minds are individual and various. Your attention is asked for only a brief statement of the current movement toward a unified science course.

Our science courses in college and high school have passed through just as distinct phases as have the development of the microscope and automobile. At the time of Linnaeus's first connection with the University of Upsala there was a marked movement there toward field work in natural history which so upset the equilibrium of the institution that Linnaeus was forced to resign. Attendant upon the development of the microscope was an awakening in microscopic technique. Modern research in the higher sciences has brought into the text books and our teaching a mass of material much of which, after trial, proves too heavy for the mind of the high school pupil. This seems to be the climax of specialization in high school science. Hitherto we have been most interested in the proper presentation of our subjects in all their fullness and beauty; the development of the child or the man has been quite incidental.

"Certain defects of science courses in content and in methods are becoming increasingly apparent. In some respects science teaching is not as closely related to the environment and experience of the pupil today as it was a quarter century ago. With the elaboration of apparatus and the increased attention to quantitative methods, there has come an aloofness from the experience of everyday life, so that the pupil may secure a high standing in physics, chemistry, biology without necessarily gaining an understanding of their applications. Moreover, teachers in science in some instances over-emphasize the importance of formal and fixed procedure and, as a result, are not alert to utilize new opportunities."

The reaction now is toward making each subject valuable and interesting to the pupil, and toward a closer articulation of the subjects as opposed to their former isolation and individualness. Courses are being compiled and fitted, being cut down here and built out there, the high places made low and the valleys filled, in order that classes may be held through the course.

The Commissioner of Education in the report for 1910 brings out the potent fact that at the then existing rate of decline, physiology will cease to be studied by 1925, physics by 1935, chemistry by 1945, and physical geography by 1960. While these statements seem overdrawn, yet they do emphasize the inefficiency of our past methods of presenting our sciences and their suicidal effect.

Without entering into the lengthy discussion of conditions which we all appreciate, may we turn to the immediate topic. Within the last decade there has sprung up a great dissatisfaction with the conventional courses. This is particularly true of the teachers in the lower years of the high school, for it is they who see the enormous loss in attendance and in interest in school work. In 1892 a committee of the National Educational Association recommended the elaboration or intensification of the first year science, geography. Gradually this became too intensive and too collegiate. In 1909, seventeen years later and five years ago, geographers inaugurated a movement among themselves to react against the inattention to human response and environment, the fitting of pupils for college rather than for life, and the suppression of interest in economic or industrial facts and factors.

Apparently thus far science teachers generally have been quite willing for the first year teachers to wrestle alone with the task of revision and adaptation. In fact the others have been eager to prune back geography to almost nothing and to graft on scions of almost everything else. But they insist that their own courses, as biology, chemistry, or what not, be left inviolate and intact.

At the present time, however, a very widespread movement is at work toward the revision of the entire high school course, science included. This work is partly under the direction of the National Educational Association and its committee on the reorganization of high school education. Its purpose and plans are given in Bulletin No. 41, 1913, of the United States Bureau of Education. This general committee presides over ten subcommittees or the high school departments: the subcommittee on natural science is divided into five others for (1) First Year Science; (2) Physics; (3) Chemistry; (4) Geography, and (5) Biology. The special committee on biology immediately upon its appointment broke up into many minor groups in order that all sections of the United States might he represented and at work. The special committee centering in Chicago, of which the speaker has the honor to be a member, includes representation from Wisconsin, Michigan, Indiana and Illinois.

It is the plan to continue this work for a period of years but to change the membership several times in order that the final report may be the work of many men and that it may be carefully formulated and revised; its first report may be collated in 1915. The general revisory committee hopes that it will:

"(a) Formulate statements of the valid aims, efficient methods and kinds of material whereby each subject may best serve the needs of high-school pupils.

"(b) Enable inexperienced teachers to secure at the outset a correct point of view.

"(c) Place the needs of the high school before all agencies that are training teachers for positions in high schools.

"(d) Secure college entrance recognition for courses that meet actual needs of high school pupils."

From this statement of aims the welding of the several sciences into a unified course is not, apparently, a definite and immediate purpose. Whether this result ensues is a question.

To our personal knowledge there is no other broad movement looking toward the reorganization of secondary education, although departmental sections throughout the country are engaged thereon. Notable among these is the Central Association of Science and Mathematics Teachers, a committee of which is at present working up a two year course in general science. Its preliminary report, which was presented at the Des Moines meeting last Thanksgiving, stated in a very general way the aims in this two year "stem" course. A successful "stem" course in general science has been worked out by W. K. Eikenberry of the School of Education, University of Chicago; it was adopted by the Agricultural Section of the Illinois High School Conference last November and is outlined in the current (January) issue of *School Science and Mathematics.*

From the accounting of the plans of the National Educational Association and of the Central Association of Science and Mathematics Teachers, and that of other isolated cases, it appears that with the possible exception of this Illinois Academy of Science, no organization has yet considered the formulation of a general course in high school science in which there shall be not only a unity or commonness of purpose and method, but even more, a close articulation or, to put it more plainly, an almost entire absence of demarcation between the natural sciences.

As heretofore given, physiology, botany, chemistry, and others have been taught and studied as independent units. When several of these sciences were in a course there was a strong staccato effect, a marked hiatus between them and a full stop at the end of each study; often there were many of these within the subject. Thus while a so-called science course was listed the pupil studied only separate units, units just as separate and distinct as Latin and history, as mathematics and English. The broad scientific truths or generalizations probably dawned upon the pupil's comprehension, if at all, long after high school days were over. The causes of this lack of articulation were at least two: the teacher and the text-book.

There exists in the minds of certain members of this committee, as probably has been stated at a previous meeting, a very admirable conception of a high school science teaching which will break down and clear away the barriers which have been the jealous boundaries of each man's domain;which will interweave the materials, the methods, and the facts of all the sciences into a fabric so smooth that a pupil entering upon the science course of a curriculum will find less difficulty in beginning new subjects each year and hence will be more apt to complete the entire course. Such a course has been well marked out in English. English now is a four-year unit and no longer solitary, independent units; the course is working excellently. In such a course the materials and information from one laboratory will be utilized in the others. The chemical, physical, biological, and geographical materials will be unified.

For example: A zoology or physiology class, when studying the animal eye, will begin with a simple lens, determination of principle and secondary foci, and image formation, and from this physical basis work into the use of a retina. This material used again in the physics laboratory, will give point or application to a cold law of optics or refraction.

And throughout the course materials of study will be interchanged and utilized until the pupil realizes that no phenomenon is to itself alone, but that all unite to make the whole. In such a course it may even come about that instead of the name plates on laboratory doors and in catalogs being called "Chemistry," or "Geography," they will be "Third Year Science," and "First Year Science."

In conclusion, then, may it be stated that by "unified science" is not meant a uniform, standardized, "cut and dried" course for all teachers, all classes and all localities, but a science the parts of which are not integers but fractions, not isolated subjects taught by trained specialists, but are portions of a broad (or deep) subject, science, taught by men who specialize in the general education of youth.

AN ANALYSIS OF SOME TEXT BOOKS IN ZOOLOGY

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In a questionaire which was sent out something over a year ago to a number of the high schools of the middle west, an inquiry was made as to the title of the text book, which is being used in the high school course in zoology. Returns indicate that there is a surprising variation in the book adopted. It is true that one text was used predominantly, yet a great many were found in use and several of these were texts of the older type, dating their publication back forty years or more. This suggested an attempt at an analysis of the various texts in zoology. With the aid of a class of graduate students, some thirty text books were analyzed. It was evident as the analysis proceeded and the results were tabulated, that the textbooks in use during the history of zoology instruction in this country indicate in the main, the changing conceptions of relative values in the instruction. It would be beyond the limits of this paper to undertake to present all of the data, so certain texts are selected from the lot analyzed which will be representative of the various types of zoology instruction which have been in vogue, and which will show, in a measure at least, the tendencies which are now at work in the instruction in high school zoology.

These figures will in no case foot up a total of 100 per cent because the topics selected are only representative ones from the group of some twenty-five topics that make up the complete analysis of the several books. The methods of getting at the figures were as follows: The book was read, and an estimate made, of the number of pages or fractions of a page (estimated in lines) devoted to each subject. Frequently, therefore, several subjects might be considered upon the same page, and these subjects might re-appear at many points in the course of the book. A summation of the pages and fractions of a page was finally made for each of the several topics and the percentage was computed which this total made of the entire number of pages of the book.

Certain tendencies are very apparent from this analysis. The oldest text evidently approaches the subject of zoology from the physiological point of view. There ensues then what may be termed the natural history point of view, stressing external features and habits. Then comes a period represented by Orton and particularly by Colton in which the morpohology

	Agassiz & Gould, Principles of Zoology, 1848.	Tenney's Natural History 1866.	Orton's Comparative Zoology, 1876.	Colton's Practical Zoology, 1886.	Davenport's Introduction to Zoology, 1901.	Kellogg's Elementary Zoology, 1901.	Linville & Kelly, Textbook of Zoology, 1906.	Kellogg's "The Animals and Man," 1911.	Davidson's Practical Zoology, 1906.	Daugherty's Principles of Economic Zoology, 1912
Comparative physiology	28.4	0.	0.5	0.9	0.	3.	7.8	8.	2.6	3.8
Embryology	8.8	3.2	4.3	1.3	5.5	1.5	3.	0.1	2.	1.7
Life History	4.3	4.7	2.4	7.3	3.4	8.6	5.5	7.9	14.5	4.3
Habits	2.8	34.1	3.4	0.	28.	11.3	6.1	14.	14.5	20.
Economic Zoology	0.	7.1	0.	0.	5.4	4.	4.8	9.5	20.	10
Geographical distribution	9.8	5.1	3.	0.	5.6	3.5	4.4	28.	0.	5.
External morphology	0.	43.6	40.	32.3	24.9	34.3	31.8	3.3	23.3	31.3
Internal morphology	0.	0.	27.4	41.6	0.2	23.3	28.8	3.2	7.6	9.6
Evolution	0.	0.	0.	0.	0.	1.6	6.2	4.9	3.8	0.

of the animal seems to be the matter of supreme moment. Linville and Kelly, the text most widely used now, is to be classed with this group. Davenport's Introduction to Zoology seems to swing back toward the old natural history point of view, emphasizing external features, especially those that relate to habits, in other words it takes the ecological view point. While not the most recent therefore, it may be looked upon as marking, perhaps, the most advanced stand in modern zoology. In the very recent books there is an evident tendency to include a good deal of practical or economical material; this is especially true in Davidson, but not as true in the Daugherty's Economic Zoology, although its name would indicate that the effort of the book is to stress this particular phase.

It is very evident from this abstract of the complete table and much more evident from the complete table itself, that the texts in zoology are far from indicating any unanimity of opinion as to the proper content of a high school zoology course.

PROGRESS OF SECONDARY SCHOOL AGRICULTURE IN ILLINOIS

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Agricultural teaching in the secondary schools of Illinois has not spread so rapidly as it has in many other states, but the growth of this phase of vocational education in the state has been sane and progressive. Two years ago there were thirty-two high schools in the state giving instruction in agriculture; the number has probably been doubled by this time.

The length of term given to agriculture in most cases is one year, many schools are offering two years by alternating courses and giving only one course each year. Only three schools to my knowledge are offering four-year courses in agriculture. Four or five schools offer special short courses during the winter for boys and girls who cannot attend school regularly.

The year of agriculture is usually given in the first year of high school and made elective to students in other classes. Warren's Elements of Agriculture is the text generally used.

When agriculture is given in the first year the students of course have very little knowledge of science to which they can relate their agriculture; on the other hand, the agriculture may furnish a motive for further study and better appreciation and understanding of the sciences which follow later. The first year agriculture often takes the place of a general science, since it invades freely into the field of botany, zoology, chemistry, physics and other pure sciences.

It may be of interest to note that at the last meeting of the State High School Conference at the University last fall, the Agricultural section recommended that a year of general science be given before, or in connection with, the study of agriculture. It was the opinion of the Section that agriculture should be taught as a vocational subject and leave the related scientific subject-matter of the various sciences to their respective fields. For example, in agriculture we should teach in regard to alfalfa, less of its botanical relationships and facts and more of its economic value and how to grow it and use it.

As the schools are now manned and equipped, more of the science of agriculture can be taught than the art. The principles governing the application of the biological and physical sciences to the art of agriculture are as well taught, and have as much educational value as the so-called pure sciences, which have been taught for a much longer period of time. The graduates from our colleges of agriculture are usually well prepared in the sciences as well as in practical agriculture, and they are therefore better prepared to teach the sciences with agriculture, than are the science men to teach the agriculture with the sciences.

Those of us who believe in agricultural education must see to it, however, that the teaching be on a sound basis and that high standards of scholarship be maintained. I do not believe there is any more danger here than there is in the teaching of other sciences. If the pure sciences are made "too pure" for high school, the fault is just as grievous as it would be were the applied sciences made merely recipes for action. The applied sciences, it seems to me, have this additional value over the pure sciences for educational purposes—in that there is opportunity in the application of the science to useful ends, to understand and appreciate the pure science as well.

As to whether the teaching of agriculture in the state at this time is well organized in relation to existing courses in the curriculum, or whether it is on the right basis, I am not able to say with any degree of correctness. The whole matter is in a changing condition, and no one seems to know what is right. Because the pure sciences had to be taught by laboratory equipment and experimental methods, may not be a reason why agriculture should be taught in this way within four walls, especially. Because one science should logically precede another, is no reason why agriculture should fit into a scheme of precedence. The danger is that our pure science men are trying to fit agriculture into a hide-bound system of textbooks, laboratories and other academic methods. Agriculture is the application of nearly all sciences, and it is out-of-doors. These facts should govern our policies and methods in teaching the subject.

Larger and better things are coming for agricultural education in our state. It may not be long until legislature fiat will place agriculture into all the schools. Many men and women are at work trying to find the best way by which agriculture in the public schools will not only contribute to the educational growth of the boys and girls of the school, but be a constructive factor in the economic and permanent growth of the state.

At the meeting of the High School Conference referred to above, the Agricultural Section adopted courses of study in general science and agriculture, and made recommendations as to books, equipment, and methods. These proceedings are being published and may be obtained soon from the writer.

RESISTANCE AND REACTIONS OF FISHES TO TEMPERATURE

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The relation of fishes to temperature has been a subject for considerable experimental and observational study in the past. The experimental work has dealt largely with the resistance of fishes to extremes of temperature, while numerous observations have been made both upon the resistance and the reactions of fishes to various temperatures. In 1853 Dr. John Davy experimented upon the resistance of a number of species of fishes to high temperatures, and in 1882, as recorded in Day's (1886) review of his work, Davy reported a considerable number of experiments upon the extremes of high temperature which eggs, fry, and adults of different species can stand without being killed. He found the egg to be more resistant to high temperatures than was the young fish and probably also than the adult. At 85° F. (29.4° C.) both the young and the old fishes were dead while the eggs still lived to hatch into normal, vigorous larvae. These results are not entirely satisfactory however, for one experiment is stated to have been performed upon the eggs, young, and adult of a given species under similar conditions. Day (1886) observed fish in the government garden in Madras, where, in December 1866, he found the maximum daily temperature of the water to be 72° F. (22.2° C.) He states that the Indian carp thrives in the lower rivers where the temperature at mid-day rises to 92° F. (33.3° C.) Carter (1887) gives a table of fishes which are sensitive or hardy in warm waters. He includes both marine and fresh water species giving the average maximum temperatures which species from the two habitats can stand. These maximum temperatures do not differ much for the two habitats being 50°-71° F. (14.4°-21.6° C.) for the fresh water species mentioned and 58°-71° F. (14.4°-21.6°C.) for those from salt water.

There are recorded cases where fishes are reported to have inhabited much higher temperatures, but most of these records are not well authenticated. Such cases will be found in the literature cited. There are also many records of fishes having endured low temperatures without injury. Many of these records are common knowledge and must be taken for what they are worth. There are, however, some definite experiments upon the relation of fishes to low temperature. Heath in 1883 tells of freezing several species of fishes in solid blocks of ice. He found that species thus frozen would regain their normal activities upon slow thawing. Other species were not so resistant, while all the species he tried died if kept in the frozen condition for more than a few hours. Pictet (1893) reports a number of experiments of the same sort. He kept gold fish at 0° C. for 24 hrs., and then slowly cooled the water to -8° to -15° C. The fishes were frozen solid and were as brittle as the ice. Upon thawing they became normal again and swam about the pan as before. When cooled to below -20° C. they could not be revived.

Much of the value of such data as the above is lost because of the failure of the workers to give specific names and accurate reports of temperatures and other experimental conditions. Thus there are numerous observations and speculations upon the influence of temperature upon the movements of fishes. Baird (1886) states that temperature is important in influencing the migrations of fishes and Verrill, according to Bumpus (1898) says the sudden death of the enormous numbers of "tile fish" in the year 1879 was probably due to a sudden lowering of the temperature of the waters usually warmed by the gulf stream. In 1899 Libbey began a series of observations to ascertain the connection between changes in temperature and the migrations of fishes. This investigation was merely a continuation of former investigations in which he had determined pretty definitely that movements of ocean currents and other changes in ocean temperatures are of very great importance in these migrations, (Bumpus '98). It is a matter of common observation among fishermen that certain fishes, for instance suckers, when they ascend the small streams in the spring to spawn, often seem to congregate in the warmer streams when there are numerous small streams of different temperatures to choose from.

PRESENTATION OF DATA

In the experiments to be briefly reported here, I have used the fresh water fishes of the creeks in the vicinity of Chicago and have performed with them two types of experiments, namely, resistance experiments and reaction experiments.

1. *Resistance Experiments*: These experiments have been of two sub-types. (1) Resistance to slowly changing temperatures, and (2) Resistance to suddenly changing temperatures. In the first sub-type the fishes were placed in a granite pan in about a liter of water (the species used have been small except in the case of the bull-head, in which case individuals not more than 4 in. long were used), at normal optimum temperature and the water was then heated gradually. The rate of heating was varied considerably in different experiments (5 min. up to 1 hr.) In killing experiments the heating was continued up to the point where death occurred; in other experiments the fish was taken out before the death point was reached.

As the water was being heated, the fishes gave very similar reactions, specific differences being quantitative rather than qualitative. At the beginning, the fish in the experiment swam about exactly as did the one in the control. As the experimental temperature increased, however, the activity of the experimental fish increased likewise. This increased activity usually became noticeable by the time the temperature in the experiment had been raised as little as 2° C. above that of the control. With the gradual rise in the temperature of the experimental pan, the activities of the experimental fish became more and more marked until in a number of instances the fish attempted to leap out of the pan at a temperature still 2°-3° C. below the maximum for the species. At this point the swimming movements were still in perfect correlation, but, as the temperature approached the maximum for the species, lack of correlation began to develop and at a temperature of 1° C. or less, below the maximum, a sudden paroxysm set in. The fish "scooted" blindly about the pan, sometimes shooting over the edge. This intense activity lasted for about 30 seconds or less, when the fish fell to its side, making no visible movements other than feeble twitchings of the gills and fins. If at this point it was immediately removed and placed in cooler water it often recovered; the possibility of recovery varied with the species and size of the fish, the more hardy species (bull-head) and the larger individuals of the other species (cyprinids) being most likely to live. The paroxysm induced by temperature resembled so much that produced in other experiments (Wells '13) by lack of oxygen and excess carbon dioxide, that analyses were made to determine the amount of these gases present during the experiments. These analyses always showed a normal amount of oxygen to be present while the amount of carbon dioxide was if anything a little less than that of the control, the diminution being due to the higher temperature of the experiment.

In the attempt to determine a definite maximum temperature for the different species used it was found that a number of factors must be considered. The species used all resisted higher temperatures when the heating was gradual, than they did when it was comparatively rapid, thus showing some acclimatization to the higher temperatures. Large fishes of a given species were usually considered more resistant than were small ones of the same species. The physiological condition of the species was found to be important; it has been found that practically all the species of fishes occurring in the rivers and creeks in the vicinity of Chicago are a great deal more resistant to many kinds of stimuli, temperature included, in March and April, just before the breeding season begins, than they are in the latter part of June and first part of July, immediately following the breeding season. In fact resistance is so low at this latter time of year, that most of the species of cyprinid minnows cannot be transported into the laboratory from creeks an hour's ride out, even though ice be taken along to keep the water cool. So low is the resistance at this time that these species often die from the shock of being seined out of the water and transferred to the fish bucket. Thus, if one were to draw the seasonal resistance curve of such fishes, it would be a rather regular curve, the highest point occurring in March and April and the lowest point in the latter part of June and first part of July, with the difference in the level of these two points a considerable one. From the low point the rise in resistance is very slow and gradual up to the latter part of September when the curve begins to rise more rapidly up to the high point in the spring.

For the above reasons it has been found impossible to state that any certain temperature is the maximum which can be endured by a given species. There are, however, definite specific differences in the resistance of fishes to temperature as well as to other factors. Of the species used in the experiments, the black bull-head (*Ameiurus melas*) was the most hardy, even though none but young of this species was used. This species could be raised to 35°-36° C. before death occurred. The other species follow in the order of their increasing resistance. Silver shiner (*Notropis atherinoides*) 27°-28° C.; straw-colored minnow (*Notropis blennius*), 28°-29° C.; common shiner (*Notropis cornutus*), 28°-30° C. (Temperatures are approximate). Field and experimental observations have been made upon a large number of other species, but will not be tabulated here.

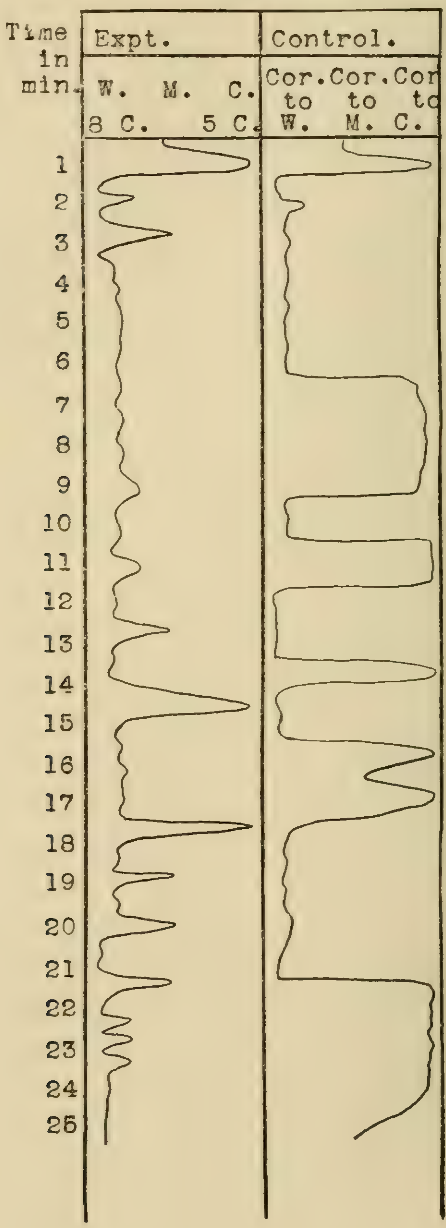
In experiments where fishes were subjected to sudden changes of temperature, the changes were made through a large number of the possible combinations existing in a range of temperature, the highest point of which is just below the general maximum for the species and the lowest point, one or two degrees above freezing. Thus one series of experiments consisted in changing adults of *Notropis blennius* from 28° C. to 3° C., from 25° C to 3° C. ,from 22° C. to 3° C., and so on down to a last change of from 10° C. to 3° C. In all the experiments the method employed was to arrange the pans of cold and warm water along side each other. The temperatures of these pans were kept constant for each test. The fish was quickly lifted from one pan to the other in the direction in which the change was to be made, i. e., from warm to cold or vice versa. The general effect of change from colder to warmer is, as has been noted, to increase the activity of the fish; the reverse change tends to diminish these activities. In general this increase or decrease of activity proceeds regularly and proportionately with the change in temperature, but at the higher and lower limits of temperature used in these experiments, there is a breaking over the bounds of normal activity and a period of abnormal activity ensues. This period has been described in the case of high temperatures, where it comes on as the temperature nears the death point for the species, and it will occur whether the heating be slow or rapid, the only difference being that with slow heating, it occurs at a higher temperature than when the heating is rapid (.5°-1.5° C. difference for the different rates tried). In the experiments where the fishes were changed from warmer to colder water it was found that with certain changes a paroxysm of activity similar to that of heating follows the transfer. To produce this result the temperature change must be sudden and relatively great. With *Notropis blennius* adults, for instance, a sudden change into water which is at least 10° C. colder than that in which the fish has been kept will produce upon the part of the fish violent activities, providing the lower temperature is not above 5°-6° C. Thus a sudden change from 15° C. to 3° C. will give the reaction, while a change from 25° C. to 13° C. will merely result in a decrease of normal movements, as rate of gill contractions, etc. A gradual cooling of the surrounding water does not result in any marked reaction at any point down to freezing (Heath '83). A typical experiment will illustrate this reaction in which the paroxysm, due to change from warmer to colder temperature occurs. "An adult *Notropis blennius* was suddenly transferred from water whose temperature was 13° C. to water of 3° C. The fish had been kept in the 13° water for four days. When dropped into the cold water, it lost all motion and gill movements could scarcely be detected. It lay thus on its side for 1 minute and 30 seconds; began to swim a little, and then suddenly "scooted" madly about the pan. This blindly violent activity lasted for 5 seconds; fish again fell to side; lay motionless for 5 seconds; pectoral fins began to twitch; gill movements weak and irregular; gradually movements of gills and fins became more vigorous until at end of 22 minutes, fish was swimming about pan; still unable to maintain equilibrium; at end of 34 minutes floating easily and normally in the cold water." The bull-head does not show any such marked reaction, however great the temperature change, its adjustment remaining within the bounds of normality in all changes from warmer to colder water. Small cyprinid fishes were less affected by the change from warm to cold than were adults of the same species, the small fishes as a usual thing not passing through a paroxysm in adjusting to the lower temperature; in any case the time required to regain normality was always less in the case of the smaller (younger) fishes of a given species. It will be remembered that the reverse was the case with regard to resistance to high temperatures. In no case was death the result of sudden change from higher to lower temperatures, though the widest range possible between the specific maximum and freezing was tried. It may well be, however, that sudden lowering in temperature does result in death where certain species are concerned. In the planting of trout fry in cold mountain streams, the change from the warm water of shipping cans into the cold water of the stream has been blamed for the high percentage of death on the part of the fry in some cases. It is a common custom among fish culturists to cool the water in the cans gradually down to the temperature of the stream, by gradually adding the colder water to that in the cans. Sudden changes from lower to higher temperatures often result in marked temporary increase in activity, but there is no loss of correlation of movements unless the higher temperature is near the maximum for the species.

In another series of experiments it was found that the time which is required for a fish to become normal in cold water is proportional to the time which it has been in the water of higher temperature. This proportionality does not hold after the fish has been in the warm water for more than an hour or two, as the fish seems to become completely adjusted by that time and further stay does not alter its actions when returned to cold water. In one series of experiments of this sort, it was found that if an adult *Notropis blennius* is transferred from 3° C. to 15° C. water for 1 minute and then back into the 3° water, it is noticeably affected, but is normal within 1 minute. If left in the warm water 5 minutes, is normal in 5 minutes after being returned to the cold; 10 minutes in warm, normal in 7 minutes in cold; 20 minutes in warm, normal in 10 minutes; 40 minutes in warm, normal in 15 minutes in cold. Up to this point adults of this species always became normal in the cold water without passing through the paroxysm. When left in the warm water for 50-60 minutes, however, the paroxysm occurred 1 minute after transfer to the cold. Further stay in the warm water had no increased effect except to increase somewhat the total time elapsing before complete equilibrium in the cold water was established. A single fish could be made to pass through the paroxysm many times, the only permanent adjustment upon the part of the fish being a slight increase in its ability to resist the shock of the sudden change from warm to cold. This was indicated by the fact that to produce successive recurrences of the paroxysm, the temperature change had to be made successively larger or the fish left for a successively longer time in the warmer water.

2. *Reaction of Fishes to Temperature*: Under this head are included a number of experiments which were performed by putting the fishes into a long narrow tank arranged so that the water flowing in at one end was of a different temperature from that flowing in at the other. The water of the two temperatures flowed to the middle of the tank and thence out through drains at top and bottom. The result was a mixing of the water, especially of the center third so that a temperature gradient was formed. This gradient was accurately determined by testing with thermometers graduated to tenths of a degree C. The fish was introduced at the center of the tank and a graph (Fig. 1) of its movements was made according to the method first used by Shelford and Allee ('13). A glance at the figure, which is that of a typical graph, will make the method and results clear. The graph is selected as typical of a large number of similar ones; it shows that the fish in the experiment reacted very definitely to the temperature gradient, selecting in this case the warmer end. Furthermore it will be noted that most of the turnings back from the colder portions of the gradient occurred some time before the fish had encountered the coldest water. Measurements showed that the fish detected and reacted to variations in temperature of no more than .1° C. All species tried were equally sensitive. Other experiments showed that fishes tend to select an optimum temperature (16°-19° C.) for they will turn back from warm water when it is above this temperature. No attempt was made to alter the optimum temperatures of the species used but it is probable that the optimum varies with the physiological state.

Discussion: The above experiments suggest that fishes possess a temperature regulating mechanism of the most delicate order. It has been shown that practically all cold blooded animals maintain body temperatures above that of the surrounding medium. Kidder (1879) showed that certain marine fishes maintain temperatures above that of the surrounding water (5°-20° C for different species). There must therefore be present in these forms, just as in warm blooded animals, a mechanism for temperature regulation. Furthermore, the convulsive activity at high temperatures and upon sudden

Figure 1, showing the reaction of a small (4 in.) micropterus dolomieu to a temperature gradient. The graph in the experiment shows a decisive selection of the warmer end. The control is neutral. Headings in control mean "Corresponding to Warm." etc.



changes to lower temperatures may be due to a failure of the mechanism to adjust to the extreme change. This explanation is supported by the fact that more adjustment was made in the case of slow heating than in the case where heating was rapid, and also by the fact that complete adjustment took place when cooling was slow. Thus acclimatization to temperature may be looked upon as resulting from an adjustment of the temperature regulating mechanism.

Experiments upon the rate of metabolism under different temperature conditions have not been carried out as yet. Just how the rate of reaction is affected, for instance, by raising the temperature of the water surrounding a fish is not certain. It is probably correct to state that in general the rate of metabolism is increased with increase in temperature, and diminished with decrease. But whether or not each degree's rise or fall in temperature increases the carbon dioxide output to the same extent is a question. Very probably the effect upon the metabolism, of changes in temperature is not the same at different points in the temperature scale, that is to say, the metabolism of a fish at 3° C. may differ from its metabolism at 25°C., not only quantitatively but qualitatively as well. Furthermore the factors that cause the fish to pass into a state of uncontrolled convulsive activity at the stages of heat and cold rigor and what heat and cold rigor are in themselves, are questions that can be answered only by means of quantitative experiments which are yet to be undertaken. At this time it seems plausible to look upon these reactions as outward manifestations of qualitative or cumulative quantitative changes in the metabolism of the organism.

TEMPERATURE AND THE DISTRIBUTION OF FISHES

It is interesting to find that forms where the activities of the individuals are so dependent upon the conditions of the surrounding environment, possess exceedingly delicate mechanisms for the detection of environmental changes. Thus it has been shown that they are able to recognize very minute differences in acidity, (Shelford and Allee, '13), (Shelford, '14) and in the foregoing pages we have seen that they are also exceedingly sensitive to slight changes in temperature, their sensitiveness in this respect far exceeding that of warm blooded animals. This fact becomes a suggestive one when thought of in connection with the life activities of fishes and the resulting distribution of these forms through their reactions. (The relation of resistance to reaction has been discussed in a former paper (Wells, '13) and will not be taken up here. If fishes can detect and will react to so small a variation in the temperature of the surrounding water as 1° C., it must be that they are continually reacting to this factor in all fish environments for such small differences in temperature must exist even in the smallest body of water. It has been suggested that temperature has much to do with the migrations of salt water fishes into fresh water streams, and the reaction experiments here outlined furnish support for such an idea. We must not attempt to limit the accuracy of such migrations to the temperature factor, however, for there are many other factors to be considered. Undoubtedly density, salinity, gaseous content, and acidity, as well as temperature, play their part in this phenomenon. The final solution of the problem must take all factors into consideration.

Summary: 1. The resistance of fishes to temperature varies with the species and with the size of the fish. Large fish of a given species are more resistant to high temperatures than small fish of the same species, but the small fish adjust to sudden changes from warm to cold more successfully.

2. There is no definite maximum temperature for a given species of fishes; the maximum varies with the rate of heating, with the size of the fish and with its physiological condition.

3. Fishes detect and react to exceedingly small (.1° C.) variations, in the temperature of the surrounding water.

4. Both the resistance and the reaction experiments indicate that the fishes experimented upon, possess a temperature regulating mechanism which is much more delicate than that of the warmer animals, though not as efficient in maintaining a constant body temperature.

5. The effect of temperature upon the migrations and distribution of fishes is obvious, since variations in temperature, far in excess of the minimum variation to which fish will react, are known to occur constantly in fish environments.

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EVAPORATION AND SOIL MOISTURE IN FORESTS AND CULTIVATED FIELDS

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I. *Evaporation.* Considerable work has recently been done in the Chicago region by Fuller[1] and others on the evaporating power of the air in such natural plant associations as the Cottonwood, Pine and Oak dunes, Edaphic prairie and Beech-Maple forest. In this work the beech-maple forest has been considered the most satisfactory standard for comparison of other plant associations and it has therefore been used in this paper as a basis for comparing the evaporating power of the air in cultivated fields. The region near Otis, Indiana, offers excellent conditions for such a study and is accessible to Chicago, therefore it has been selected for this work. The beech-maple forest for this investigation is bordered by cultivated fields of wheat and oats which have soils of a similar nature. The methods of cultivation in the wheat field are evidently superior to those in the oat field, as indicated by the greater depth of humus and the texture of the soil. The evaporating power of the air and the soil moisture of these habitats has been determined during the season extending from May 3 to August 23, 1913.

In determining the evaporation power of the air the Livingston[2] porous cup atmometer was used according to the usual methods employed. All instruments were properly standardized before being set up and at frequent intervals during the season. By comparison of these coefficients with that of a standard atmometer, all readings were reduced to a common

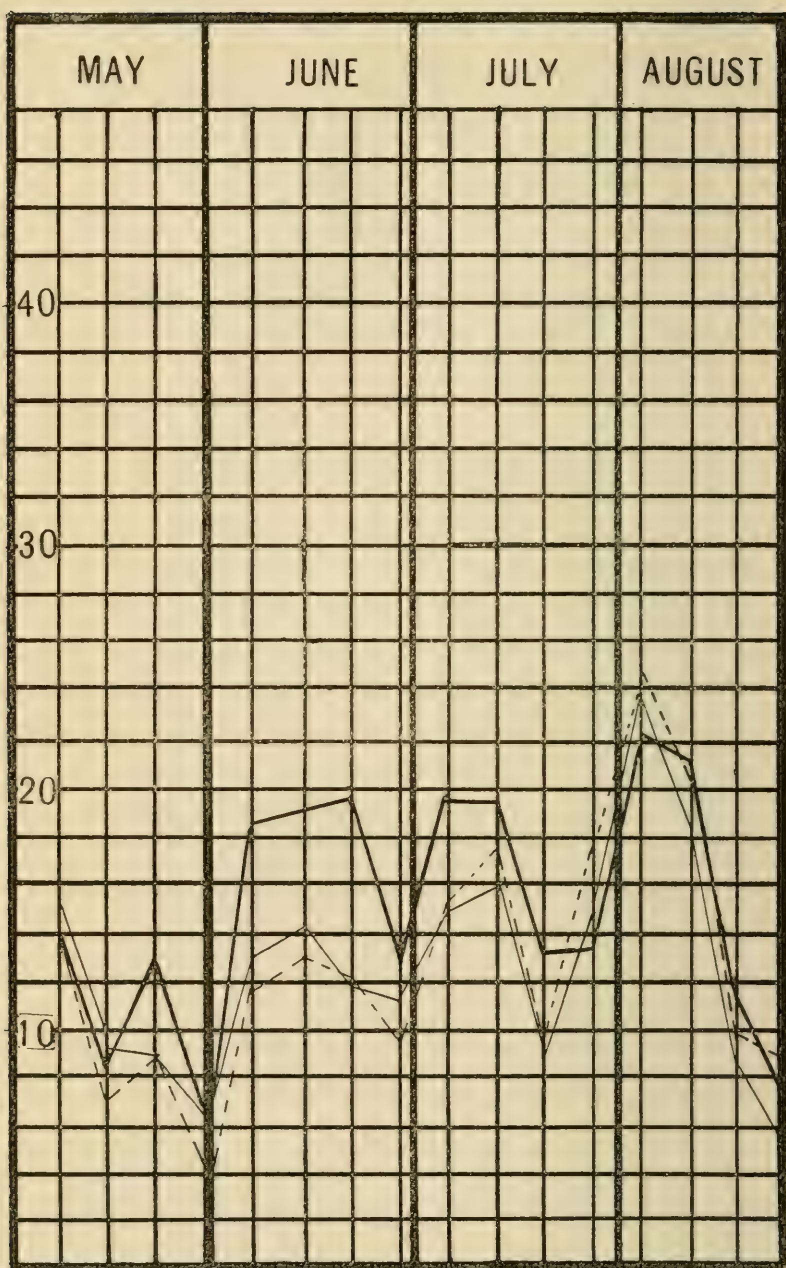

Figure 1: Graphs representing the range of evaporation at three stations in the beech-maple forest.

basis. Throughout the season readings were taken once each week and the results reduced to the average daily loss for each week. The accompanying graphs have been made with the average daily loss in cubic centimeters as ordinates and with weekly intervals as abscissae.

In the beech-maple forest three stations were established in representative positions. During this season the herbaceous vegetation was somewhat sparse and therefore probably modified conditions from time to time but little. One of these stations was placed on the crest of a low ridge which gave it somewhat more exposure to the wind. In figure 1, this station, represented by the heavy line, has a rather higher evaporation rate altho it is fairly parallel with the other two stations. Three stations were established in the wheat field, which had also been sown with clover, with more or less uniform exposure. One of these stations was surrounded by taller wheat and more vigorous clover, which produced a luxuriant crop after the wheat had been harvested. In figure 2, this station, represented by the heavy line, has a slightly lower evaporation rate. Three stations of uniform exposure were established in the oat field about June 8th, which gave fairly parallel curves. The average of these curves is plotted in figure 3 (c). No records were taken after the oats were harvested early in August.

II. *Soil Moisture*: Through the work of Briggs and Schantz[3] and others the *wilting coefficient* has been established as a more or less satisfactory standard for the comparison of available growth water for plants in various soils. It represents the water content above which the growth takes place, and is expressed in percentage of dry weight of the soil.

In the determination of the soil moisture in the habitats studied, weekly samples of soil were taken from representative stations at depths of 7.5 cm. and at 25 cm. below the surface. This soil was brought to the laboratory in closed jars where it was weighed and dried at a temperature of about 104 degrees C., until it reached a constant weight and a percentage of water was calculated on the basis of this dry weight. The wilting coefficient of the same soils were obtained by the wax seal method of Briggs and Schantz,[3] and also by the indirect centrifuge method of the same workers. In figures 4 and 5 graphs have been plotted representing the range of soil moisture on the ordinates and the weekly readings on the abscissae. Upon these same diagrams the wilting coefficients have been represented in dotted lines. The available growth water is therefore represented by the intervals between soil moisture and wilting coefficient.

Figure 2: Graphs representing the range of evaporation at three similar stations in a wheat field.

While there is a general agreement between the individual and average curve representing soil moisture, several points of variation may be accounted for by corresponding changes in conditions. In figure 4 the variations noted about July 1st may be ascribed to weather conditions, while in figure 5, the ripening and harvesting of the wheat may affect the changes noted at this time since the corresponding evaporation was not high.

Weather conditions may account for the decrease in soil moistures about August 1st, since there is a corresponding increase in evaporation.

In figure 5 the wilting coefficient of two strata coincide. This is probably due to deep cultivation rendering the soil more or less homogeneous.

As pointed out by Fuller[1], the most significant comparisons are those shown in table 1, under growth water. The mean growth-water of the beech-maple forest is taken as the standard and represented by 100. This furnishes a quantitative statement of the relation of different habitats in their mesophytic conditions. Another comparison of habitats may be shown by the ratio between the mean weekly growth water and the evaporation rate for the same time. While it may be claimed that these units are not comparable, the ratio seems to give a quantitative relation between the habitats which is thought to be valuable. Since the growth water represents the available supply for plant growth and the evaporating power of the air represents the demand made by the plants on the available water, it seems advisable that such a comparison be used in this kind of work.

SUMMARY

The evaporation rate at the surface of cultivated fields is somewhat parallel to that of the climax beech-maple forest and shows corresponding variations due to changes in weather conditions. After crops are harvested the evaporation rate is greatly increased, due to the increased exposure.

In the beech-maple forest the soil moisture is much higher in the stratum due largely to the great amount of humus. In this association the wilting coefficient was reached only once during the season.

In the wheat field the upper stratum shows a marked response in soil moisture due to periodic rainfall. In this association the soil moisture falls decidedly below the wilting coefficient after the wheat is harvested.

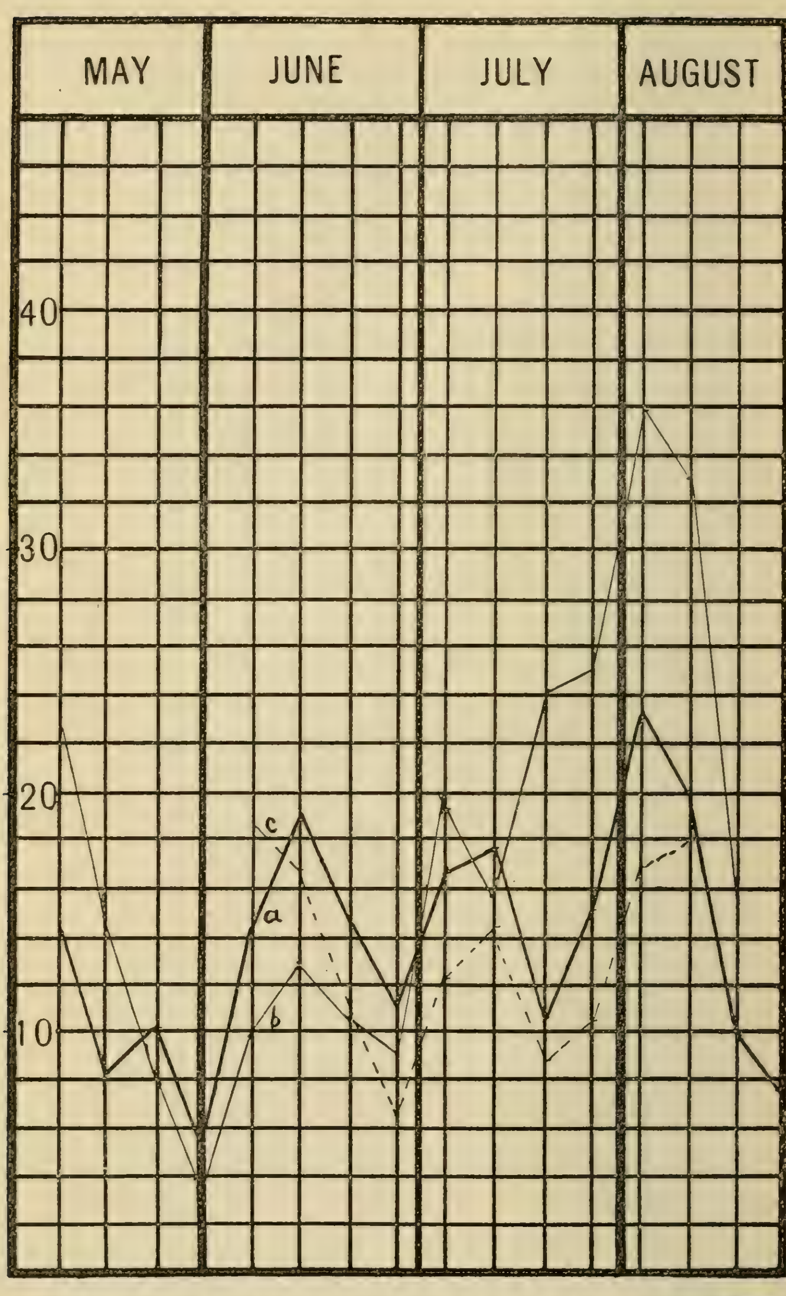

Figure 3: Graphs representing the average evaporation of three stations each in (a) beech-maple forest, (b) wheat field, and (c) oat field. ("1" represents the time of harvesting wheat).

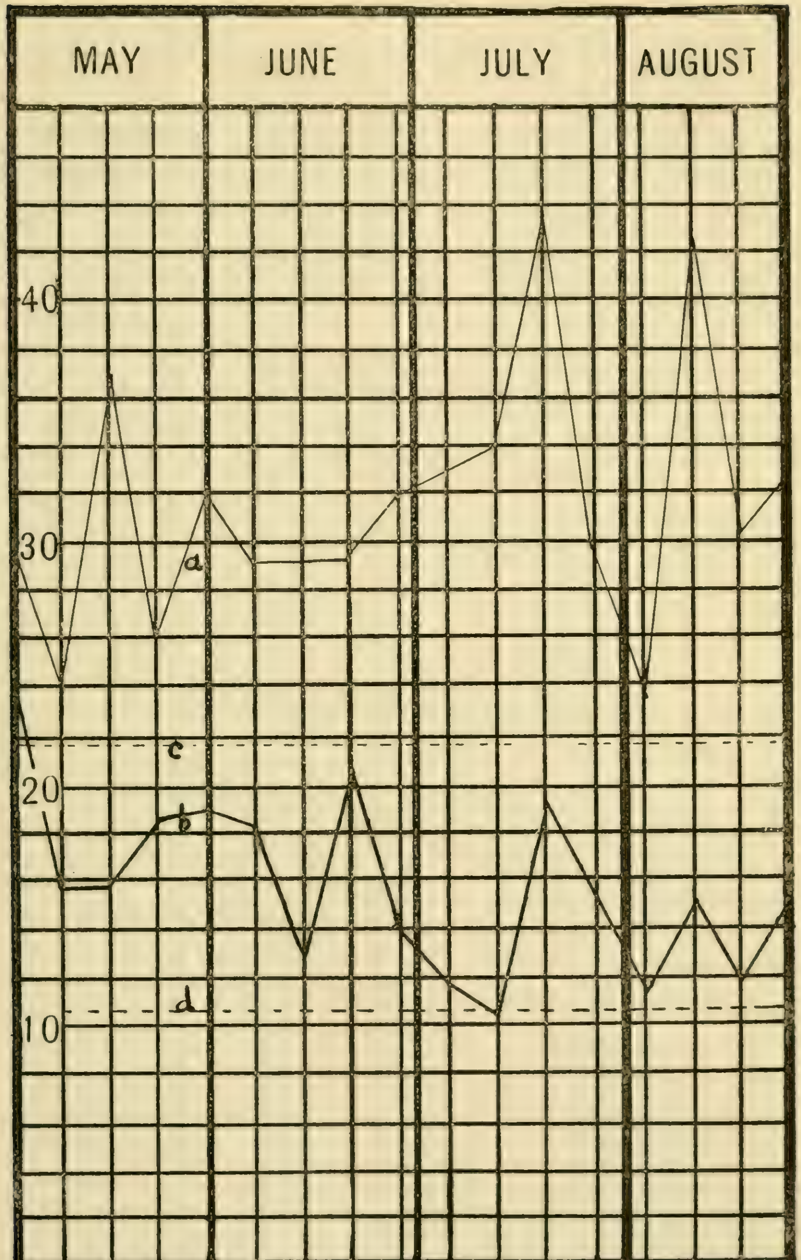

Figure 4: Graphs representing soil moisture in beech-maple forest at (a) 7.5 cm., (b) 25 cm. below surface. Also wilting coefficient of soil moisture at (c) 7.5 cm. and (d) 25 cm

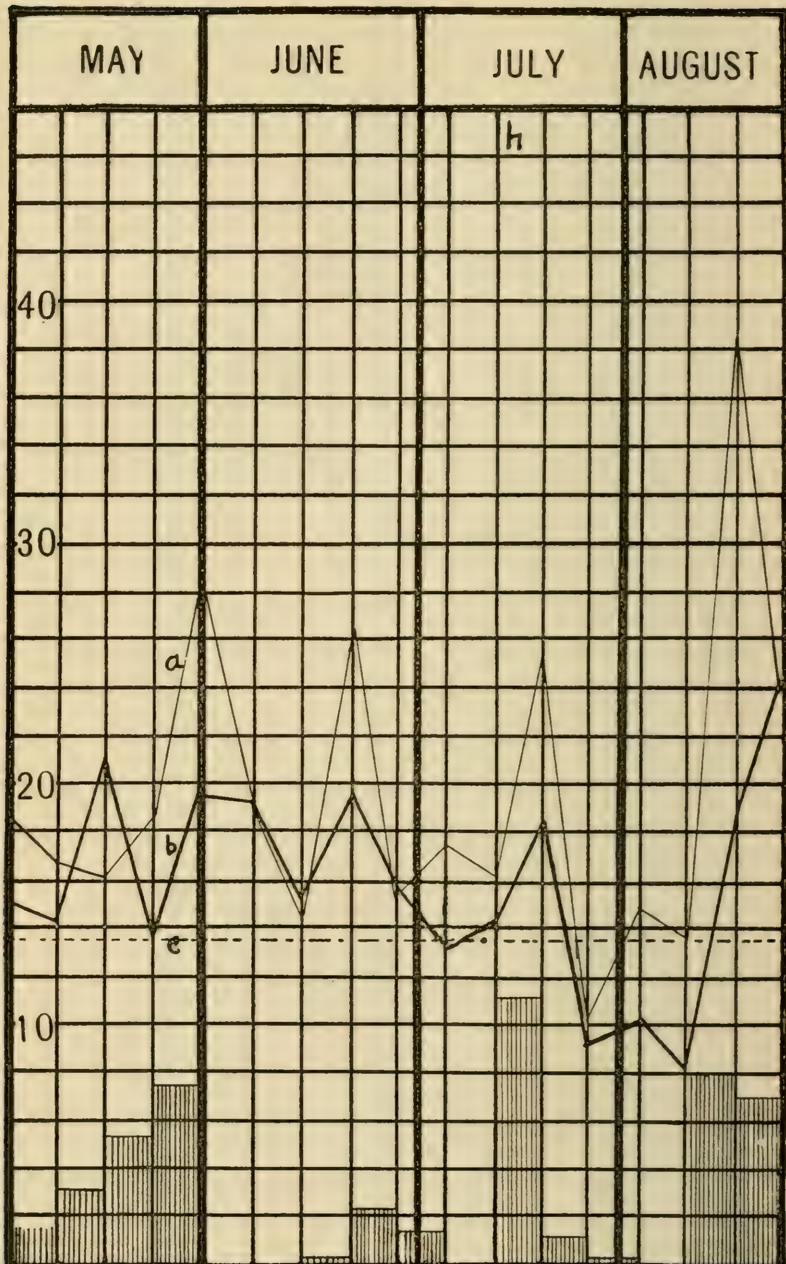

Figure 5: Graphs representing soil moisture in wheat field at (a) 7.5 cm., (b) 25 cm. below the surface. Also the wilting coefficient of soil at (c) 7.5 cm. and 25 cm. Weekly rainfall at bottom graph.

The upper stratum of the oat field also shows considerable variations which correspond more or less to those in the wheat field.

In order to determine the relation of climatic conditions to crop production the work on soil moisture and evaporation should be extended to deeper strata of soil and to higher strata of the atmosphere. Soil and air temperatures should also be recorded in these extended strata since such temperatures probably are directly effective on plant growth. The amount of precipitation and of irrigation water should also be recorded throughout the year, together with the soil conditions which effect the conservation of the same. The distribution and stages of development of the stem and root systems should be determined from time to time as the crops progress. The osmotic force of the roots of various crops in comparable stages of development may also be of interest in this connection.

The above methods of determination can be profitably applied to any crop at different stages in its development and under different methods of cultivation in order to obtain a quantitative statement of the relative effectiveness of methods of cultivation.

I wish to acknowledge many helpful suggestions by Doctor George D. Fuller, under whose direction this work has been done.

TABLE I.

Wilting Coefficients and Mean Percentage of Growth-Water in Various Associations from June 1 to August 16, 1913

Name of Association	Depth in cm.	Wilting Coef.	Growth-water Per cent	Growth-water Mean %	Growth-water Comp. Amts.	Ratio of Evap. & growth-water
Wheat field	7.5	13.6	6.3	3.65	55.	5.25
1913	25.0	13.7	1.4			
Oat field	7.5	14.1	9.6	6.00	90.	2.17
1913	25.0	10.5	2.4			
Beech-Maple	7.5	21.8	10.4	7.35	100	2.02
1913	25.0	10.6	4.3			
*Beech-Maple	7.5	13.5	5.5	4.25	100.	2.00
1911	25.0	9.5	3.3			
*Beech-Maple	7.5	13.5	5.0	4.5	100.	1.18
1912	25.0	9.5	4.0			

*Taken from Fuller's data in the same region.

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SOIL MOISTURE AND PLANT SUCCESSION

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The direct source of the water supply of plants being the moisture in the soil, the amount of this moisture is evidently of the highest importance to vegetation. This has been recognized by many leading ecologists and phytogeographers, but very little data have been made available as to effects of definite quantitive amounts of this moisture upon the vegetation or of the amount and range of the soil moisture in different plant associations. This has been largely due to the difficulty in relating the amount of soil moisture to the production of vegetation. It is clear that there can be no direct relation between the percentage of water present in soils and the amount available for plant growth, for a sandy soil with 15 per cent of moisture is at or near saturation, while a stiff clay with 15 per cent of water is so dry that all plants wilt in it, even with a humid atmosphere.

Efforts have been made to establish a standard by which the actual water content of soils could be related to plant production. *Clements*[1] determined the amount of water remaining in soils when pronounced wilting occurred, and regarding this as non-available, termed it the *echard,* while the difference between the amount actually present in the soil and the echard was the available water, or *chresard. Livingston*[2] recognized that the *water-holding capacity* of soils varied and had a fairly constant relation to the soil moisture conditions. Then *Briggs* and *McLane*[3] determined the *moisture equivalent* of soils by the application of a centrifugal force of 1000 times that of gravity thus providing a method of measuring and comparing the retentiveness of different soils for moisture acted upon by a definite force. This had the advantage of being measured in absolute terms, and of being reproducible within narrow limits of error. It remained for *Briggs* and *Shantz*[4] to refine the methods of determining the percentage of water in soils when permanent wilting occurs in such a plant as the standard Kubanka wheat, giving the *wilting coefficient,* and further to show that a constant relation existed between the moisture equivalent and the wilting coefficient; that is,

$$\frac{\textit{moisture equivalent}}{1.84} = \text{wilting coefficient}$$

They also clearly demonstrated the fact that plants continue to take water from the soil long after the wilting coefficient is reached. The writer, believing that none of the water absorbed from soil whose moisture content is below the wilting coefficient is used for the growth of the organism, has used *growth water*[5] for the soil moisture in excess of the wilting coefficient.

METHODS

The soil moisture determinations here reported were made in the plant associations described in this paper during the years 1911-12, from the first of May to the end of October. In making the determinations, weekly samples, each consisting of 200 to 250 grams of soil, were taken in each of the associations at depths of 7.5 cm. and 25 cm. In order to provide against unnecessary error, each sample consisted of two portions of some 100 grams each, taken from spots several meters apart, care also being taken that no soil was taken nearer than a meter to holes where previous samples had been dug. The soil was placed in wide mouthed jars, tightly sealed, brought to the laboratory, weighed and dried at a temperature of 100° to 104° C. until it reached a constant weight (about 5 days). The percentage of water to the dry weight of the soil was then calculated.

The wilting coefficients of the same soils were determined by both the direct and indirect methods of *Briggs* and *Schantz*[4].

THE ASSOCIATIONS STUDIED

The series of associations studied consists of a succession beginning with a pioneer association dominated by the cottonwood, *Populus deltoides,* developed upon the sand dunes at Millers, Ind., and extending through succeeding associations, at the same place, dominated by *Pinus Banksiana* and *Quercus velutina,* known respectively as the pine and oak dunes. In the usual order of succession in the Chicago area the black oak forest is succeeded by one composed of the more mesophytic white oak, *Q. alba;* the red oak, *Q. rubra,* and the hickory, *Carya ovata,* and usually designated the oak-hickory forest. The example of this association studied is situated at Palos Park, Ill., and the results from this station have already been reported[6]. The climax of the succession is found in the mesophytic beech-maple forest which is found well developed at Otis, Ind. A description of the vegetation of these associations has been given by *Cowles*[7] and also by the writer in his more detailed report of these studies.[8]

An examination of the accompanying table (Table I) will show the growth-water for the ten weeks of midsummer for

1911-1912. The results for the cottonwood dune as already published for 1911[5] show two rather surprising things, namely, a remarkably small wilting coefficient, only 0.8 per cent at both depths, and a surprisingly constant supply of growth-water. Considered in relation to the wilting coefficient, the soil moisture actually present in the sand is continuously at least twice the amount of water necessary for the growth of such a plant as wheat. This is in striking contrast with the desert-like aspect of the association due to the almost complete absence of herbaceous undergrowth. Doubtless this constancy is largely due to the dry mulch maintained by the action of the wind and to the small quantities of water withdrawn by the sparse vegetation. The record for 1912 differs in no important particular from that of the previous year.

In the next association, the pine dune, the accumulation of humus increases the wilting coefficient to 1.1 per cent at 7.5 cm. and 1.0 per cent at 25 cm. The amount of growth-water is less than in the previous association and at three separate weeks during both of the years it quite disappears. Reasons for this failure are to be found in the comparative absence of the conserving dust mulch and in the much larger demands made by the denser stand of vegetation.

In the oak dune a slight decrease of humus seems to be indicated by the slightly lower wilting coefficient, but on the whole there is a somewhat greater supply of growth-water.

The water supply for the oak-hickory forest has already been reported in detail[6] and it is only necessary here to point out that the growth-water more than doubles that in any previous association.

The climax beech-maple forest shows the accumulation of humus in its wilting coefficient of 9.5 per cent at 25 cm., being increased to 13.5 per cent at 7.5 cm. The large and unfailing supply of growth-water is indicative of truly mesophytic conditions. As in the other associations, the upper stratum shows the larger amount of variation. Comparing the two seasons, it will be seen that while the averages are about the same, the year 1912 shows a much greater uniformity in the range of moisture supply.

GENERAL CONCLUSIONS

An examination of Table I as well as a general knowledge of conditions of growth in these associations indicates that only during midsummer is there any scarcity in the supply of the habitats. It has therefore seemed desirable to limit our comparisons to this period of stress, and to establish the rather arbitrary limit of the 10 weeks from the last of June to the first of September. A summary of these weeks appears in Table I.

TABLE I.

Wilting coefficients and mean percentages of growth-water in the various associations during the 10 midsummer weeks of 1911-12:

Association	Depth in cms	Wilting coefficient	Growth-water				Ratio between evaporation and growth-water
			1911	1912	Mean	Comp. Amts.	
Cottonwood dune	7.5	.80	2.2	1.8			
Cottonwood dune	25.	.80	2.6	2.0	2.15	49	11.7
Pine dune	7.5	1.10	.9	.7			
Pine dune	25.	1.00	1.7	1.3	1.15	26	10.7
Oak dune	7.5	1.10	1.4	1.4			
Oak dune	25.	.90	.8	1.5	1.27	29	9.37
Oak-Hickory	7.5	9.0	3.2				
Oak-Hickory	25.	9.5	3.3		3.3	75	2.78
Beech-Maple	7.5	13.5	5.5	5.0			
Beech-Maple	25.	9.5	3.0	4.0	4.4	100	1.81

No one can realize more fully than does the writer the limitations of the data or the desirability of having them supplemented by more numerous determinations, especially from deeper strata. These limitations will make the conclusions more or less provisional and subject to modification and correction in the future. The most interesting and profitable comparisons are doubtless those to be made from a consideration of the growth-water data shown in Table I., and especially as expressed in the sixth and seventh columns, which contain the mean percentages of growth-water and the comparative amounts, the beech-maple forest being taken as a standard and its mean growth-water represented by 100. In the five associations that form the succession, the mean growth-water for midsummer of the two seasons will be found, if we except the cottonwood dune, to form a progressive series, the most mesophytic association having the largest amount. This was exactly what was supposed to be the situation, but hitherto no quantitive data of such moisture relationships have been available, it has been impossible to tell how much an association differs in its water conditions from the preceding or succeeding association. As has already been stated, the cottonwood dune, with a larger and more constant water supply than the two succeeding associations, must owe its surplus to the conserving power of its dust mulch and to the small outgo due to the paucity of its vegetation.

The comparative amounts of growth-water indicate even more clearly the relationship existing between the available water supplies of the associations, and should serve to emphasize the fact that the progressive increases in the water retaining power of the soil, due largely to its increased humus content, must play no inconsiderable role in causing the succession here, culminating in the mesophytic beech-maple forest. More investigation must be made before more definite comparisons can be made.

Another and still more important comparison may be instituted among the associations under investigation by considering the ratio between the average mean weekly evaporation rates for the 10 mid-summer weeks of the years 1910-1912, and the mean growth-water for the same period. These ratios are expressed in the final column of Table I. In determining these ratios it is recognized that the units of measurement in the case of the evaporation and the soil moisture are not directly comparable. Still it is thought that the comparison is a legitimate one, and institutes a quantitative comparison of the mesophytism of the habitats which is valuable and exceeds in accuracy anything hitherto attained. It is true that these habitats are limited to the lower stratum of the aerial and the upper strata of the subterranean vegetation, but as previously pointed out, these are the portions of the habitat that are of critical importance in the establishment and maintenance of associations, because in these the seedlings, both woody and herbaceous, develop. An extension of the habitat by the addition of the higher strata of the air and the strata of the soil containing all the aerial and subterranean portions of the vegetation would doubtless modify and decrease the steepness of the gradient between the various ratios.

The ratios may either be compared directly, remembering that the mesophytism of the various habitats varies in inverse ratios with the numbers expressing these ratios, or the beech-maple forest may again be taken as the standard and represented by 100, when the direct ratio of the mesophytism of the corresponding portions of the oak-hickory forest, the oak dune, the pine dune, and the cottonwood dune will be respectively 65, 20, 17, and 15. These comparative values of the moisture factors show such a surprising rate of increase as one proceeds from the pioneer to the climax associations, that it cannot be doubted that such a change in water conditions must be one of the chief, if not the most important cause of the succession of associations from the more xerophytic to the mesophytic.

SUMMARY

1. These data represent the range of soil moisture in the upper subterranean strata of the vegetation of the various associations.

2. The rate of evaporation in the cottonwood dune association both by its great amount and by its excessive variation, seems a quite sufficient cause for the xerophytic character of the vegetation and for the absence of undergrowth, in spite of the constant presence of growth-water.

3. The pine and oak dune association resemble one another closely in their supply of growth-water. The former is slightly more xerophytic during the midsummer weeks.

4. The amount of growth-water in the various associations varies directly with the order of their occurrence in the succession, the pioneer being the most xerophytic.

5. The ratios between the evaporation and growth-water in the beech-maple forest, oak-hickory forest, oak dune, pine dune, and cottonwood dune associations have been shown to have comparative values of 100, 65, 20, 17, and 15 respectively, and the differences thus indicated are sufficient to be efficient factors in causing succession.

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FURTHER NOTES ON THE POST-GLACIAL BIOTA OF GLACIAL LAKE, CHICAGO

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At the Chicago meeting of the Illinois Academy of Science in 1911[1], the writer presented certain facts concerning the biota contained in the sedimentary strata of the bed of Glacial Lake Chicago. Since that time data have been accumulating which have added largely to our knowledge of the life of these early days. Attention has also been directed to the southwestern portion of Michigan, bordering Lake Michigan, which contains sedimentary deposits referable to several of the lake stages.

To understand the northward migration of the life, one must have clearly in mind the condition of this part of the country as the great ice sheet melted back into the Michigan basin. There was at first a large glacial lake in the Kankakee marsh area, known as Lake Kankakee, which extended northeasterly almost to South Bend; later came Lake Dowagiac which extended northeasterly up the area now occupied by the great Dowagiac swamp; still later, after this drainage was largely abandoned, a long arm of glacial Lake Chicago extended into Michigan and connected with the Grand River outlet of glacial Lake Saginaw.

Just how rapidly the biota followed the retreating ice is not known, but we may safely infer that certain hardy types (as for example the Physas, some Lymnæas, Sphaeria, Planorbis, etc.), took advantage of the new water courses at a very early time. It is this cold temperate, almost subarctic fauna that is found in the earliest deposits of glacial Lake Chicago.

Many, if not all, of the lakes in southwestern Michigan, (including Berrien, Cass and Van Buren counties), contain marl beds of post-glacial origin. The life entombed in these marl deposits, consisting of mollusks, reached these lakes, for the most part by direct migration from the region south of the Wisconsin ice sheet. In what manner and by what routes they came is one of the most interesting questions open to the student of zoogeography. Three localities in the region under discussion contain the remains of a more ancient life, one previously known, the others here recorded for the first time.

1. Trans. Ill. Acad. Sci., IV. pp. 108-116, 1912.

1. Buchanan, Berrien County

Two miles west and a little north of Buchanan, Berrien county, is a stretch of low land known as Bakertown marsh. The marsh was previously a lake about three miles long and a mile wide, but is now grown up in marsh grass and is practically dry. A ditch about a mile in length drains the marsh, and exposes the strata, which exhibit the following section:

VIII.	Marsh bog	16 inches
VII.	Recent peat	20 inches
VI.	Peat and drift wood	10 inches
V.	Lake silt (no shells)	8 inches
V.	Semi-ligneous peat	12 inches
III.	Shells and lake drift	8 inches
II.	Blue Clay	7 inches
I.	Quicksand	7 to 10 feet

The thickness of the sedimentary deposits above the sand is 81 inches, or 6 feet, 9 inches.

The quicksand (stratum I) evidently represents the period of Lake Dowagiac when the glacial waters rushed down the lake into the Kankakee River, loaded with sediment. The clay, (stratum II), represents a quieter stage, after the main drainage had shifted to the Chicago outlet. Stratum III probably represents the bottom of a larger St. Joseph River, for the species of naiads represented are mostly of the river type. An arm of Lake Chicago extended up the St. Joseph River from Benton Harbor to about the vicinity of Berrien Springs[2] and the river drained into this extension of Lake Chicago.

The fluviatile mollusks may have reached this locality from two sources; (1), by way of the Chicago outlet, across Lake Chicago and up the St. Joseph River; or (2), by way of the Kankakee when it was connected with the St. Joseph and Dowagiac rivers via South Bend. The mussels are mostly of the river type and their natural migration route would be by way of a river. Just how long after the formation of Lake Chicago the St. Joseph-Kankakee drainage persisted is not definitely known, but it is believed to have continued for some time in a more or less modified form. The naiades represent a climate fully as warm as the present and they could not invade the waterways of the icy drainage. Certain boreal types of mollusks could and evidently did take advantage of this waterway at an early stage. It is probable that both drainages were used and the fauna represents a mixture of the two migrations. This stratum may be safely correlated with the Tolleston stage of Lake Chicago.

2. See Leverett, Illinois Glacial Lobe, plate XV.

The five and a half feet of silt and peat above the shell deposit represent the later stages of this locality and indicate its change from a river to a lake and finally to its present marsh-bog character. The mollusks (42 species) and other remains of life found in this deposit are listed below.[3]

MOLLUSCA

Symphynota compressa (Lea)=*pressus* Lea
Symphynota costata (Raf)=*rugosa* Barnes
Anodonta grandis footiana Lea
Anodontoides subcylindraceus (Lea)
Alasmidonta calceola (Lea)=*deltoidea* Lea
Eurynia iris (Lea)=*novi-eboraci* Lea
Eurynia ellipsiformis (Lea)=*spatulatus* Lea
Lampsilis ventricosa (Barnes)
Sphaerium simile (Say)
Sphaerium striatinum (Lam)
Pisidium near *abditum* Prime
Pisidium compressum Prime
Pisidium medianum Sterki
Pisidium milium Sterki
Pisidium pauperculum Sterki
Pisidium roperi Sterki
Pisidium ventricosum Prime
Pisidium near *vesiculare*
Campeloma integrum (Say)
Campeloma integrum obesum (Lewis)
Campelima subsolidum (Anth)
Pleurocera elevatum (Say)
Goniobasis livescens (Menke)
Valvata tricarinata Say
Amnicola limosa (Say)
Amnicola lustrica Pilsbry
Physa ancillaria Say
Physa integra Hald
Physa heterostropha Say
Ancylus rivularis Say
Planorbis antrosus Conrad
Planorbis campanulatus Say (=*bicarinatus* Say)
Planorbis trivolvis Say
Planorbis deflectus Say
Planorbis parvus Say
Galba obrussa (Say)=*disidiosa* authors
Galba humilis modicella (Say)
Lymnaea stagnalis appressa Say
Carcychium exiguum (Say)
Succinea ovalis Say
Strobilops labyrinthica (Say)
Vitrea hammonis (Ström)=*radiatula* Ald

ARTHROPODA

Head of dipterous insect.

VERTEBRATA

Mammut americanus (Kerr)

Considerable driftwood was observed, but none was identified. The shells occurred in little colonies, just as they are found today. It is probable that these colonies represent localities where the water had brought together and deposited

3. Walker Nautilus, XI., p. 121; XIII., p. 34; 55.

a quantity of dead shells, drift wood, and other debris, and not colonies of living shells. The mastodon skulls were found in and under the stratum of semi-ligneous peat, showing that these animals waded into the river after the shells were deposited. They were probably caught in the boggy bottom and were drowned.

The multitude of lakes which dot the surface of Berrien, Cass and Van Buren counties, especially in the swampy area near the Dowagiac and St. Joseph rivers, nearly all have marl deposits correlative with the later stages of the Great Lakes history. Many of these date from the glacial Lake Dowagiac, which had its outlet through the Kankakee River, while others are relics of the early stage of Lake Chicago when an arm extended into Michigan and up the valleys of the PawPaw and Black rivers.

2. Magician Lake, Cass County

In the northwestern part of Cass county, and also partly in Van Buren county, is a lake of considerable size, known as Magician Lake. This body of water empties into the Dowagiac River through Dowagiac Creek. Swampy tracts and old shore lines indicate this lake was once considerably larger and deeper. On the north shore, and about midway of the lake, near the summer resort known as Magician Beach, is an old embayment which is a swampy terrace about two feet above the water line. The upper three feet are peaty and boggy; beneath this stratum is a marl bed of unknown depth, which is filled with mollusks, of which the following species have been identified:

Unio, fragments
Sphaerium simile (Say)
Pisidium compressum Prime
Pisidium variabile Prime
Pisidium noveboracense Sterki
Pisidium splendidulum Sterki
Pisidium adamsi affine Sterki
Valvata tricarinata Say; Central carina almost absent in some specimens.
Ammicola limosa (Say)
Ammicola lustrica Pilsbry
Paludestrina nickliniana (Sea)
Physa integra Hald
Physa ancillaria Say
Physa walkeri Crandall
Physa gyrina Say
Planorbis antrosus Conrad
Planorbis antrosus angistomus Hald
Planorbis parvus Say
Planorbis deflectus Say
Planorbis hirsutus Gould
Planorbis exacuous Say

Galba palustris (Müller).
Galba galbana (Say)
Galba obrussa decampi (Streng)
Galba obrussa exigua (Lea)
Lymnaea stagnalis apressa Say

Of the above 25 species and varieties, 5 species formed about 90 per cent of the bulk of the material. These species are indicated in the order of their abundance.

Valvata tricarinata
Planorbis parvus
Amnicola lustrica
Paludestrina nickliniana
Galba obrussa decampi

Lymnaea stagnalis appressa, Galba galbana, and *Physa walkeri* do not live in the lake at the present time. This fauna probably migrated up the St. Joseph River to the Dowagiac River and then up Dowagiac Creek.

3. Pipestone Lake, Berrien County

In the northeastern part of Berrien county, near the Van Buren county line, is another lake of about the same area as that of Magician Lake. This body of water drains into the St. Joseph River through Pipestone Creek. Marl beds similar to those of Magician Lake occur in Pipestone Lake, and have yielded a number of species of mollusks as indicated below:

Sphaerium simile (Say)
Sphaerium striatinum (Say)
Pisidium compressum Prime
Pisidium variabile Prime
Pisidium splendidulum Sterki
Valvata tricarinata Say
Amnicola limosa parva Lea
Amnicola lustrica Pilsbry
Physa integra Hald
Physa heterostropha Say
Planorbis trivolvis Say
Planorbis antrosus Conrod
Planorbis antrosus angistomus Hald
Planorbis antrosus striatus Baker
Planorbis campanulatus Say
Planorbis deflectus Say
Planorbis hirsutus Gould
Planorbis parvus Say, many monstrosities
Galba obrussa decampi (Streng)
Galba obrussa exiqua (Lea)
Lymnaea stagnalis appressa Say.

These mollusks evidently migrated to Pipestone Lake either by way of the Chicago outlet, the St. Joseph River and Pipestone Creek, or up the Kankakee and St. Joseph rivers. It is probable that both routes contributed to the formation of both of these small lakes.

My thanks are due to Dr. Bryant Walker of Detroit, Michigan, and to Dr. V. Sterki of New Philadelphia, Ohio, for assistance in identifying critical material.

THE PHYSIOLOGICAL AGREEMENT AMONG THE ANIMALS OF ANIMAL COMMUNITIES

BY V. E. SHELFORD, UNIVERSITY OF ILLINOIS

All the animals occupying a relatively uniform habitat constitute an animal community. A physiological agreement exists among the animals of communities. The object of this investigation was to determine the extent and character of such agreement with particular reference to the rapids community of a large creek. Considering the community as a whole there is

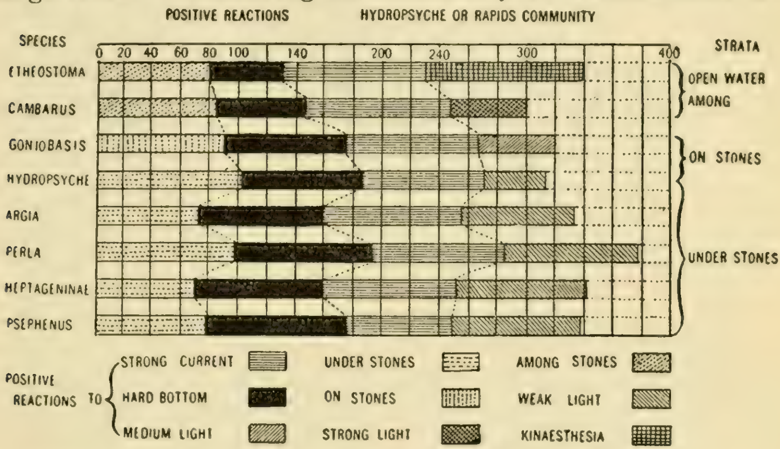

Figure 8
Biol. Bull. Vol.. XXVI, p. 313. Fig. 40.

(1) a *general agreement* in reactions to certain factors; (2) *disagreement in respect* to factors differing in intensity vertically, and (2) *a sharp difference* between *the rapids community* and other communities.

Figures 8 and 9 are introduced to show the character of the agreement and disagreement in a rapids community, and the fact that the pool community is different but remains unsolved. Noting first figure 8, we note a noteworthy agreement in reaction to bottom and to current. The preference for hard bottom in these experiments means the avoidance of sand as sand and hard bottom were present in the experiment. Animals living under stones were under stones in darkness in the experiment. The snail (*Goniobasis*) which lives on stones was found on stones in the experiment. The darter (*Etheostoma*) and the crayfish (*Cambarus*) which live among stones were found among stones in the experiment. Thus the different animals differ in their reactions to bottom and are in disagreement with reference to their vertical distribution in nature. Turning to reactions to light we find a comparable difference.

Animals living beneath stones show a preference for weak light, those living on stones, medium light, those among stones, strong light. If we were to study the community in full we would find that reactions to many other factors are of importance.. Associative memory no doubt plays a role. Thus there

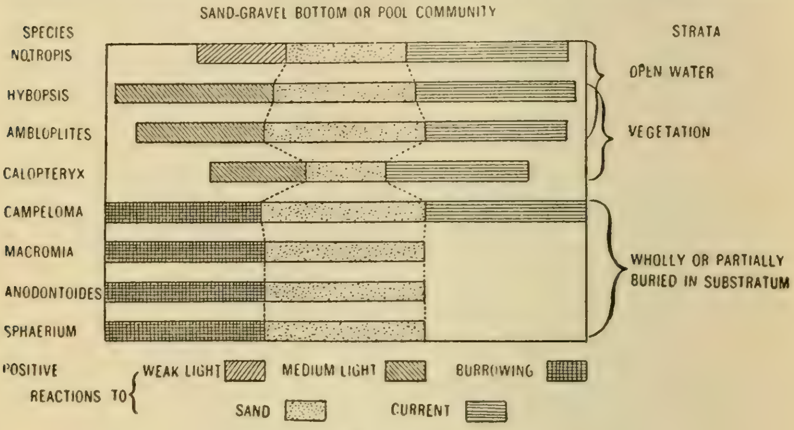

Figure 9
Biol. Bull. Vol. XXVI, Fig. 4, p. 314.

is agreement in reaction to factors of prime importance in the community habitat as a whole and disagreement in respect to factors differing strikingly in the different situations in which the animals live within the community habitat.

The diagram of the pool community, Fig. 9, is introduced to show how strikingly it differs from that of the rapids community. Though agreement is not indicated here on account of the incomplete character of the experiments, our experience with the reactions of pool fishes and invertebrates to chemical differences in water, suggests that such differences may be of much importance to all the species. The difference between the two communities is emphasized by the presence of a strong preference for sand bottom and by the presence of the burrowing habit, both of which are wanting among the animals of the rapids community. The non-burrowing pool species are positive to current; the burrowing species do not respond within ordinary lengths of time. The reactions to light show much more sharp negativeness than in the case of darters and crayfishes of the pool community. The community is clearly unsolved and a large amount of experimentation would be necessary to determine suitable tests for these animals and then all the animals of both communities should be put through all the tests, new and old. A series of new tests must be added for each new aquatic community and all the old tests must be so modified as to secure responses from all the animals. Thus the labor involved in comparing a number of communities is great.

DESCRIPTION OF FIGURES

Figure 8, showing the agreement and disagreement of the reactions of the animals of the rapids community. Note agreement of reaction to bottom and current and disagreement in two other reactions related to the level at which the animals live. These results were obtained by placing the animals under experimental conditions in which they had a choice between different kinds of bottom, different strengths of light, and in which their behavior in a water current was noted. In the case of water current the percentage of animals headed up stream is given. When headed up stream animals are said to be positive to current. In the case of the other stimuli the percentage of animals in the kind of conditions available was noted and the animals are said to be positive to the conditions in which the greatest number are found. Thus we note that the darter (*Etheostoma*) was 80 per cent among the stones and is said to be positive to this kind of situation. It will be noted that if the animals had been 100 per cent positive to the various stimuli the entire 400 units should be occupied in the diagram. This could be true only if there were no other factors entering into the reactions of the animals. The common names of the animals are as follows: *Etheostoma,* darter; *Cambarus,* crayfish; *Goniobasis,* snail; *Hydropsyche,* Caddis worm; *Argia,* damsel fly; *Perla,* stone fly; *Heptageninae,* may fly; *Psephenus,* water penny.

Fig. 9. Suggestions as to the probable agreement and disagreement in the reactions of the animals of the unsolved pool community on the basis of a total of 300 per cent. The common names of the animals are as follows: *Notropis,* shiner; *Hybopsis,* river chub; *Ambloplites,* rock bass; *Calopteryx,* damsel fly; *Campeloma,* snail; *Macromia,* dragon fly; *Anodontoides,* mussel; *Sphaerium,* small bivalve.

RECENT VIEWS CONCERNING ELECTRICAL CONDUCTANCE IN SOLUTIONS

L. I. SHAW, NORTHWESTERN UNIVERSITY

In 1801 Nicholson and Carlysle discovered that solutions conduct, and ever since that time the question as to how they conduct has been more or less of an open one.

Let us first briefly consider two of the older theories of conductance. The first one which we will consider is the theory advanced by Grotthuss. According to this one, the substances existed in the molecular state in the solution. On the passage of the current the molecules first lined up, then split off and then rearranged. This procedure was continued as long as the current was passed. Clausius showed this to be incorrect, for the reason that Ohm's Law holds for liquid as well as metallic conductors, and if this is so, no electrical energy is used up in breaking up the substance, but on the other hand, the ions must already exist in the solution. The reason for a substance breaking up on going into solution he ascribed to the collisions due to molecular motion in the solution. Fortunately for Clausius, at the same time Williamson was working on the subject of etherification and came to the same conclusion independently. This theory of Clausius dominated chemistry for many years, in fact until Arrhenius came forward with the one which is familiar to you all. This theory may be stated thus:

When a substance is dissolved in water and conducts the electric current, it is dissociated into ions more or less completely, depending on the dilution, and that the degree of this dissociation may be calculated from (1) the conductance of the solution, (2) the lowering of the freezing point or raising of the boiling point, and (3) the osmotic pressure.

Let us now consider first some of the reasons, in a general way, why this theory is favored, after which we will take up some of the objections, and then consider some of the very recent work.

THINGS IN FAVOR OF THE THEORY

1. Many aqueous solutions conduct and many non-aqueous do not.
2. When a current is passed through a solution of an electrolyte there is an immediate production of discomposition products.
3. Many or most electrolytes show too great a lowering of the freezing point, raising of the boiling point, and too great an osmotic pressure.
4. All or nearly all strong bases when neutralized by strong acids show the same heat of neutralization.
5. The instantaneous interaction of chemicals when electrolytes and the slow or lack of action when they are not.
6. Some gases, when dissolving in water, do not obey Henry's Law.
7. The hindering of a reaction by adding something that will give like ions.
8. Most substances dissociate more as the dilution is increased.
9. Faraday's Law.

OBJECTIONS TO THE THEORY

1. Non-aqueous solutions do conduct.
2. In some solutions the conductivity does not increase on dilution.
3. In some the dilution makes the conductivity increase, some increase then decrease, some decrease, and some decrease then increase.
4. There are instantaneous reactions in non-aqueous solutions.
5. Neutralization of non-aqueous solution does not always give the same heat of reaction.
6. The degree of dissociation as calculated by the three different methods do not always agree.

7. The hindering of a reaction by adding something which does not give like ions.

8. Faraday's Law holds for non-aqueous solutions.

9. The equation for degree of ionization calculated on the basis of concentration does not always hold, even for typical salts.

These are only a few of the reasons, and many more might be given on each side.

Let us now consider some of the recent work, more in detail.

The work of Walden of Rega apparently showed that there was a direct parallelism between the dissociation power as indicated by the conductivity and the dielectric constant. Without a doubt, this was true for the one solute that he used, but it has been equally well established by work done at Wisconsin and by some unpublished work done in our laboratory, that this relation does not hold in all cases.

Creighton of Halifax on the other hand gives results in a recent paper which show that for aniline in acetophenone the Nernst-Thomsen rule does hold. Also Davis of Dalhousie College found the same relations for rosaniline hydrochloride in organic solvents, as Walden did for his solute.

Thornton of the University of Durham, says in explanation of some high values for the dielectric constant obtained for some liquids such as water, that it is an effect depending on the electrical conductivity.

To get his results Walden assumed that the conductivity of the solvents which he had especially purified was due to ionization. This is likely not the case for the reason that the conductivity is dependent upon the mode of purification. In this connection I will recite the recent work of Corvallo, published in C. R., in which he states that he obtains ether so pure that its conduction is very likely due to impurities.

Viscosity is recognized as having considerable influence on the conductivity of a solution. Lloyd of Alabama has recently showed that he gets entirely different maxima at 50° C. than he does at 100° C. for the same solutions, and this difference he attributes to changes in viscosity. Pratolongo of Milan determined the conductivity of a solution of citric acid with hydrochloride, arsinous, or phosphoric acids dissolved in it, and found that each addition reduces the specific conductivity. This effect is ascribed in part to an increase of the viscosity of the solution by these additions.

Some very interesting results have been obtained by the prolonged passage of an electric current through ammonia or ethyl alcohol, when it was found that the conduction increases with the length of time of the passage of the current. Methyl alcohol does not behave in a like manner. This work was done by Corvallo and published in C. R. 156.

The work of Kahlenberg of Wisconsin with instantaneous precipitations of anhydrous copper chloride from anhydrous copper oleate solutions by means of a dry solution of hydrochloric acid in benzene is doubtless familiar to you all. These solutions are all non-conductors and the resulting liquid with the precipitate in is a non-conductor. However, recent work by Cady and Lichtenwalter of Kansas has shown some interesting things in this connection. To take a typical example they passed dry hydrochloric acid gas into copper oleate solution, and while neither one alone was a conductor, nor was the resulting mixture a conductor, they found that just previous to the precipitation, which they say was not instantaneous, that the liquid showed considerable conductivity. At this time I do not care to comment on this work further than to say that it seems to throw light on one of the apparent exceptions to Arrhenius' theory.

The state which a substance is in, apparently has considerable influence on whether the solution conducts or not, even in organic solvents. This was shown by Lloyd of Alabama, who found that when Molybdenum pentachloride is dissolved in an organic solvent giving green solutions, that they have a conductivity of the same order as water solutions of common salts. Differing in this respect, however, that the molecular conduction decreases with dilution. When this same salt dissolves, giving red-brown solutions, they do not conduct appreciably.

With these few considerations, I want, in a way, to ask your pardon for the disconnectedness of the material presented, which, however, is rather forced on the writer by the disconnectedness of the views.

CYCLONIC DISTRIBUTION OF WEATHER ELEMENTS FOR DAVENPORT, IOWA.

ANTON D. UDDEN, AUGUSTANA COLLEGE

The daily weather forecasts issued by the United States Weather Bureau stations are largely based upon the easterly progress of successive areas of high and low pressure across

Figure 10. Number of Observations in each tract.

the continent. The accuracy of the predictions depends upon the determination of three factors, namely: the probable path of the cyclone or anti-cyclone during the next twenty-four hours; its probable translational velocity; and the *distribution* of the meteorological elements within the highs and lows.

The purpose of this paper is to describe some of the results obtained from a statistical study of the distribution of the weather elements for Davenport, Iowa. The present work is based upon a method of study devised by Dr. J. A. Udden and described by him in a paper entitled, "On the Cyclonic Distribution of Rainfall."*

The plan consists in constructing a hypothetical cyclonic area

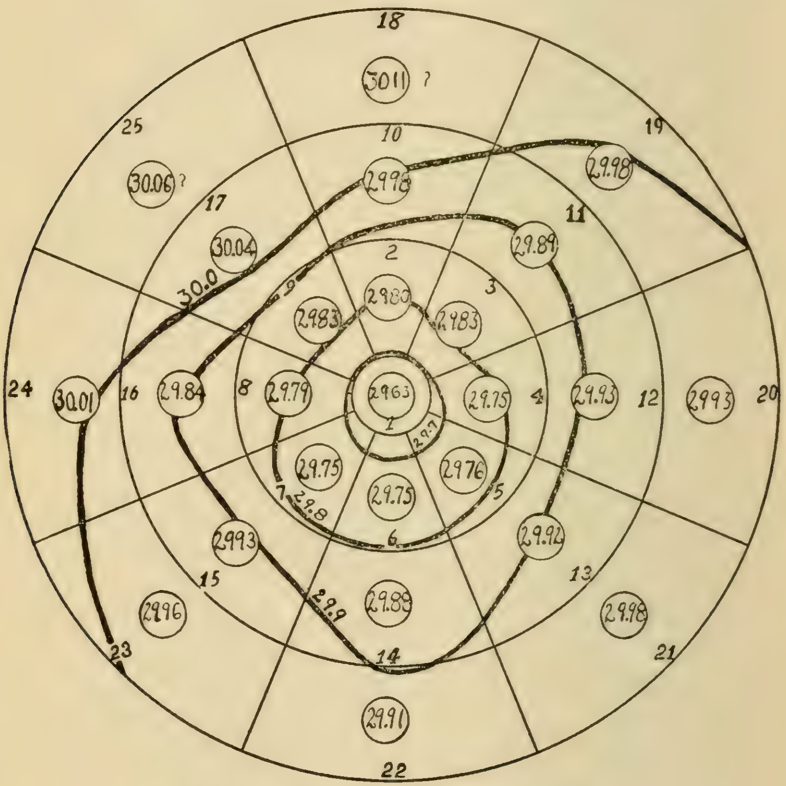

Figure 11. Barometric Pressure

as shown in Fig. 10. Four concentric circles are drawn whose radii measure respectively 100, 400, 700 and 1000 miles in length. Eight radii 45 degrees apart and extending from the outer to the inner circle delimit 25 tracts within the hypothetical cyclone. These are numbered from 1 to 25 in the figure.

*Augustana Library Publications, No. 4, Denkman Memorial Library, Rock Island, Ill.

The next step is simply to determine from a weather map the particular tract of the cyclone in which Davenport lies and to record the simultaneously existing weather conditions. By obtaining a sufficient number of observations it is possible to ascertain the average weather conditions when Davenport is situated in any given area of the cyclone.

The present study is based upon an examination of the

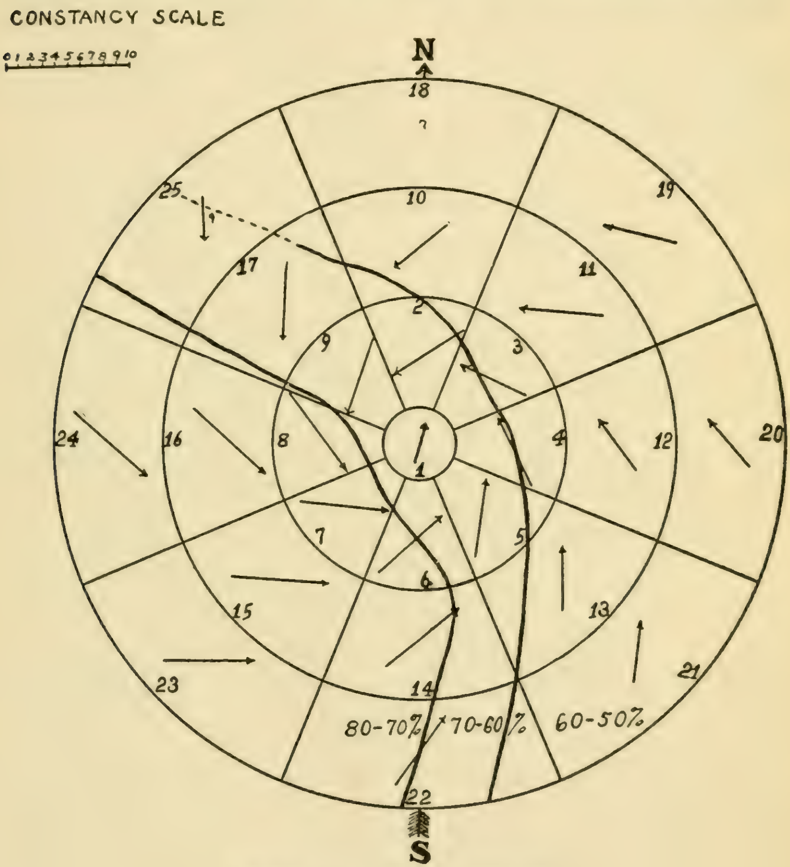

Figure 12. Wind Direction

morning and evening weather maps for a period of about twenty years. A total of 4508 observations have been secured. These are distributed unequally among the 25 tracts of the hypothetical cyclonic area as seen in Fig. 10. The maximum number of observations, namely 521, occurs in tract 15; in this position Davenport lies about 550 miles southwest of the center of the low. The fewest observations, 17 in number, are found in tract 18, when the center of the low occurs over the Gulf coast. The number of observations in each area is sufficient to give a fairly reliable average of the weather conditions in all tracts except 18 and 25. For this reason the averages in these tracts have been checked by a question mark in the accompanying diagrams.

The number of observations given in figure 10 also show that the center of the low passes north of Davenport about

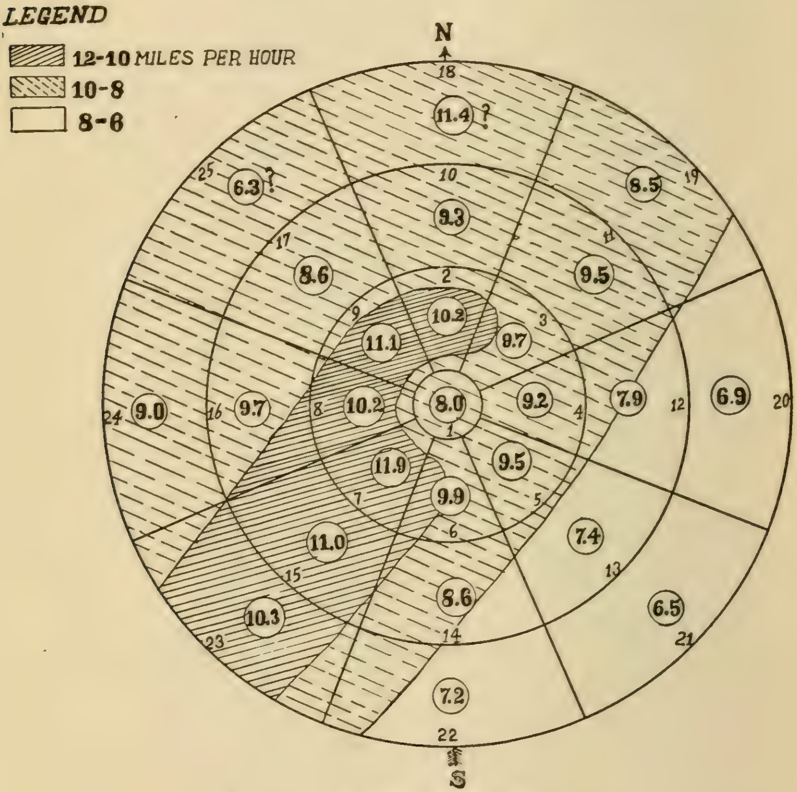

Figure 13. Wind Velocity

twice as frequently as to the south. It passes east and west of the city with about equal frequency. These results evidently depend upon the location of Davenport with reference to the storm tracks traversed by the cyclones.

The distribution of the barometric pressures is shown in figure 11. The numbers within the circles give the average pressure in inches for each tract. The heavy concentric lines represent isobars which conform to the pressure values. In general the pressure decreases radially toward the center. At the same time it is also evident that the pressure gradient is steepest in the northwest and less toward the southeast. The pressure distribution has a direct bearing on some of the results presented below.

The arrows in figure 12, indicate the prevailing wind directions in the various tracts of the cyclone. They exhibit the general spiral motion of the wind characteristic of cyclones. Upon nearing the center the winds deviate increasingly toward the right. The wind direction in the central tract possesses a southwesterly component of motion. The lengths of the ar-

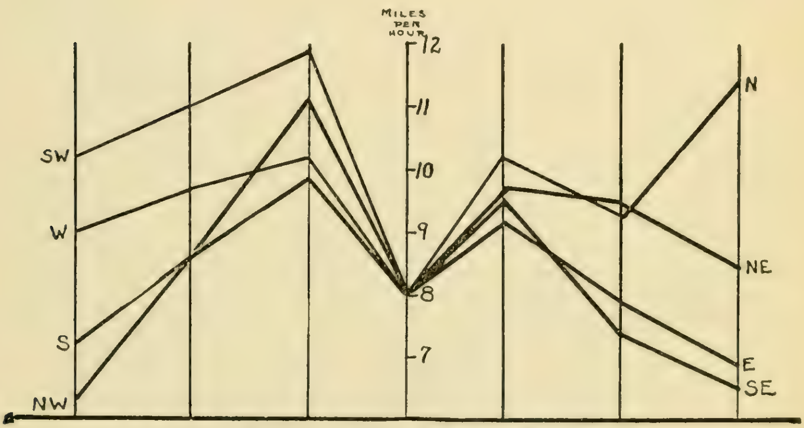

Figure 14. Wind Velocity

rows in figure 12 are proportional to the relative persistence or constancy of the wind in the average direction. The constancy of the wind shows two distinct variations. It increases radially inward to a maximum and drops to its lowest value at the center. This variation is evidently due to a similar radial variation of the wind velocity shown in figure 13. The greater inertia of the higher wind velocities renders them less liable to be deflected by accidental causes. Secondly, the constancy of the wind is greatest in the southwest and decreases toward the northeast. This is shown in figure 12, by the three areas embracing wind directions whose constancy values are, respectively 80-70 per cent; 70-60 per cent; and 60-50 per cent. The high constancy of the wind direction in the southwest is probably due to several causes; the uninterrupted sweep of the wind over the level western prairies; the high wind velocity in this region as shown in figure 13; and to the relatively stable temperature conditions. The low constancy value in the east and northeast may be accounted for in a similar manner. The presence of the Great Lakes would probably increase the variability; the average wind velocity is low; and the prevailing high temperatures in the east and southeast would introduce an unstable element. (The data in this paragraph are based only on the A. M. observations.)

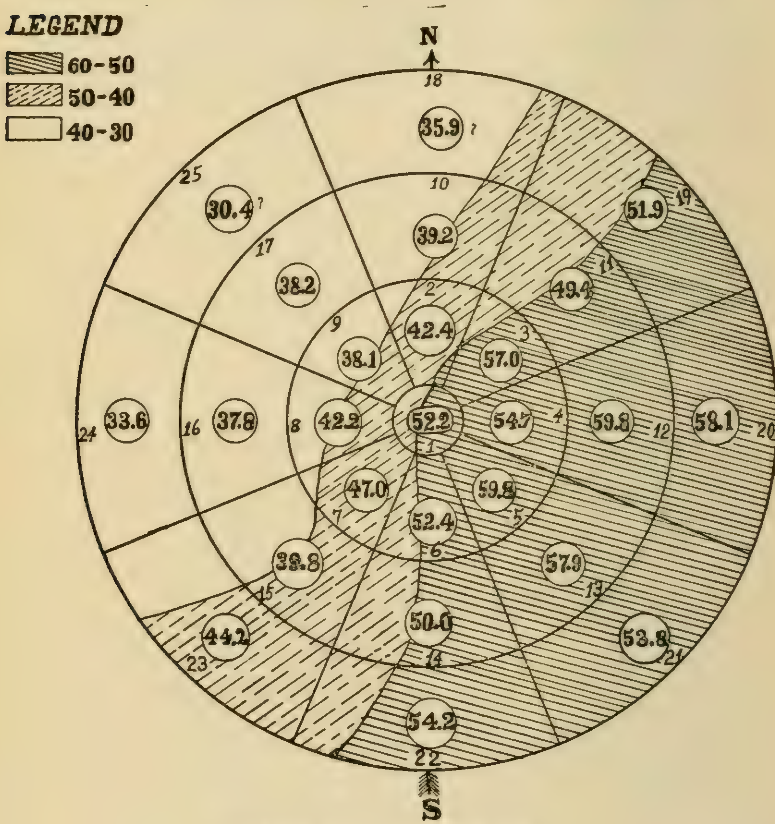

Figure 15. Temperature

The distribution of wind velocities within the cyclone is given in figure 13. The average wind velocity in miles per hour for each tract is indicated by the number inscribed in the small circle. The variation in wind velocity may be separated into two components. First: the shaded areas show that the higher wind velocities prevail in the west and northwest while the lower velocities occur to the southeast of the center. This condition is a direct consequence of the pressure distribution previously described. The high wind velocities in the southwest are probably due to the coincidence in direction of the prevailing westerlies with the westerly cyclonic winds of these tracts. Secondly, the wind velocities increase radially inward to a maximum and drop to a common minimum at the center. This is illustrated more clearly in figure 14, in which the wind velocities are plotted as ordinates. The abscissa is a diameter of the hypothetical low and the ordinates have been erected at

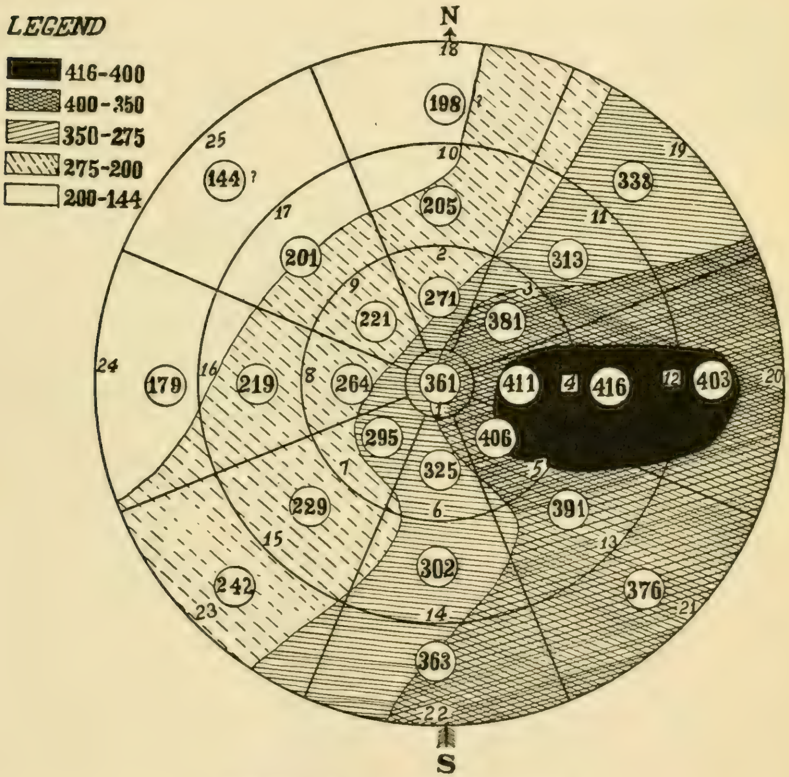

Figure 16. Vapour Pressure

points corresponding to the centers of the tracts along the diameter. A scale of wind velocities in miles per hour is marked off upon the central ordinate. The broken lines indicate the respective radial variations in wind velocity. It is seen that the velocity increases radially to a maximum at the innermost concentric area and then falls to a minimum of 8 miles per hour at the center. These facts are in agreement with the general knowledge of the nature of cyclones.

The distribution of temperatures within the cyclone is shown in figure 15. The average temperatures for the various tracts are inscribed within the small circles. The temperature distribution is also represented graphically by the shaded areas which enclose temperatures ranging from 60-50, 50-40, and 40-30 respectively. The highest temperatures are seen to prevail in the southeast quadrant of the cyclone. This is due to the southerly direction of the winds in that region. The low tempera-

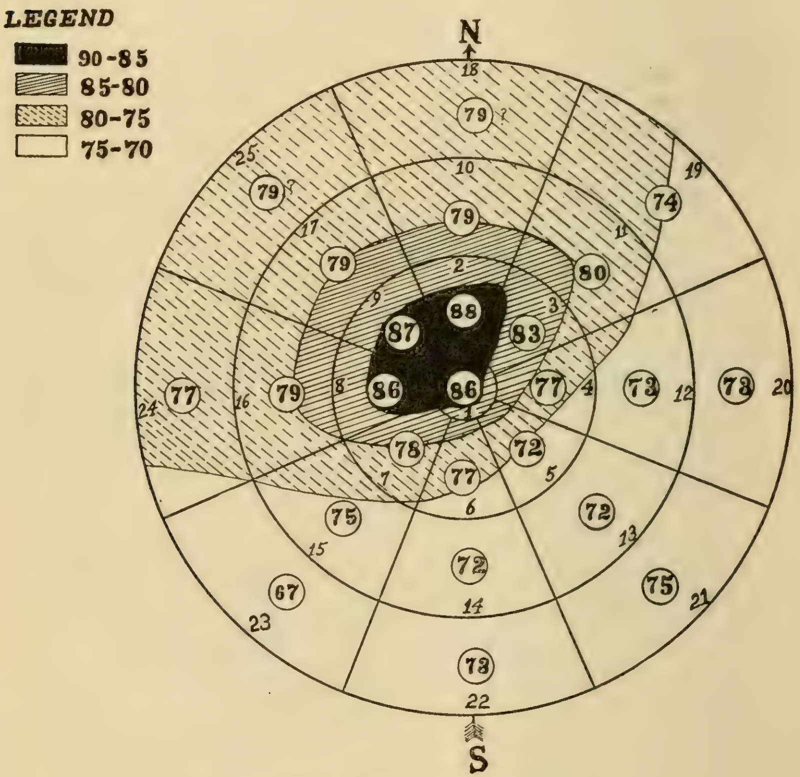

Figure 17. Relative Humidity

tures in the northwest are produced by the cool winds from the north.

The distribution of vapour pressure is similar to that of the temperature. This is seen by comparing figures 15 and 16. The vapour pressure is greatest in the southeast and least in the northwest. The vapour pressure also increases radially toward the center. The similarity of the vapour pressure and temperature distribution is a necessary consequence of the fact that the vapour pressure varies directly with the temperature although not at the same rate.

The distribution of the relative humidity, amount of cloudiness and frequency of precipitation are shown in figures 17, 18 and 19 respectively. The relative humidity is expressed in per cent; the amount of cloudiness is given in the usual scale of 1 to 10; and the frequency of precipitation is also expressed in per cent. The three diagrams are strikingly similar. On the whole it is seen that the values of these three quantities

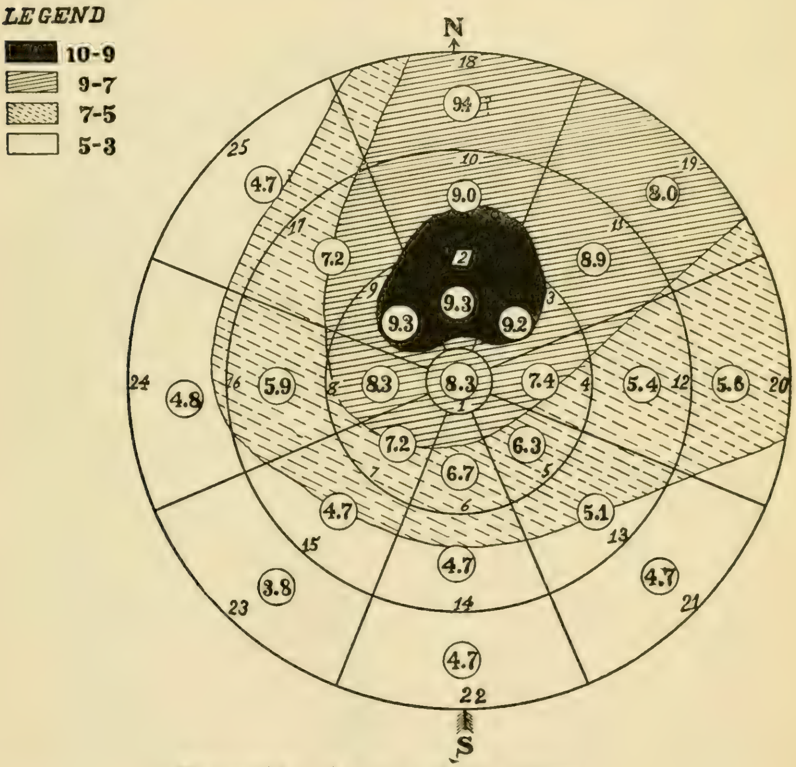

Figure 18. Amount of Cloudiness

are greater in the northern half of the cyclone than in the southern half. The lowest values occur farthest to the southeast of the center. The highest values are found in the dark areas immediately north and slightly west of the center of the cyclone. These areas are relatively small and sharply defined. Judging from the close coincidence in the distribution of the relative humidity, amount of cloudiness and frequency of precipitation, it appears safe to assume that the amount of precipitation follows a similar distribution. These results seem to stand quite at variance with the statements sometimes found in elementary textbooks on meteorology to the effect that the values of relative humidity, amount of cloudiness and precipitation are highest to the east and southeast of the center of the cyclone.

Several factors probably contribute to the location of the areas of greatest relative humidity, cloudiness and rainfall north of the center of the low. Local conditions evidently of-

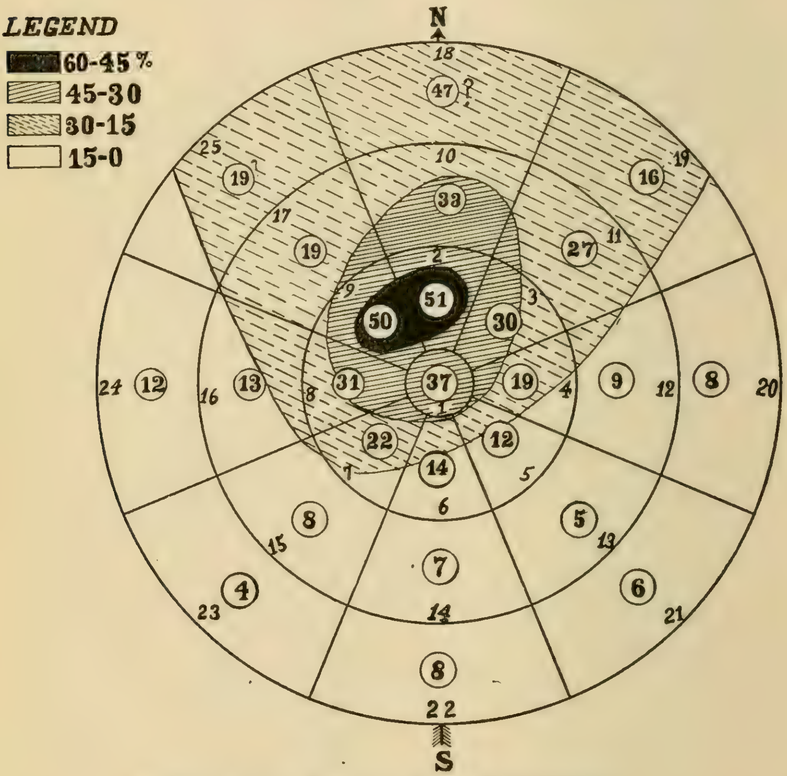

Figure 19. Frequency of Precipitation

fer an important modifying influence. The presence of the Great Lakes to the northeast of Davenport probably constitutes an important cause, also the presence of numerous small lakes, and rivers in Wisconsin and Minnesota. The humidity of the winds sweeping over these areas is probably increased by an appreciable amount. Furthermore the Great Lakes and other bodies of water would tend to decrease the temperature of the northerly winds in the summer time, thus raising the relative humidity. In the winter time the warmer temperature of the lakes might contribute to the general upward motion of the air in cyclones with the consequent adiabatic cooling.

That the presence of smoke bears a direct relationship to cloudiness seems now to be an established fact. Such a relationship appears to be suggested in figure 18. It is seen that the distribution of maximum cloudiness trends toward the northeast. The action of smoke as a factor in producing this may be stated as follows. Large volumes of smoke are poured into the atmosphere by such manufacturing cities as Gary, Chicago, Milwaukee, Minneapolis and many other cities lying roughly within a quadrant northeast of Davenport. From the figure it is seen that the maximum amount of cloudiness occurs in Davenport when the city is so situated that it lies in the path of the winds blowing over the smoke producing area. On the other hand the quadrants northwest, southwest and southeast of Davenport are relatively free from smoke and the amount of cloudiness registered at Davenport when the winds come from these regions is comparatively low. In order to be reasonably certain that the matter here presented is a real cause of cloudiness it would be necessary to actually count or estimate by an appropriate method the number of particles of dust carried by the atmosphere with the wind from the various directions.

In the preceding paragraphs the author has described in part the cyclonic distribution of weather elements for Davenport, Iowa. The topics considered include: The barometric pressure; wind direction; wind velocity; temperature; vapour pressure; relative humidity; amount of cloudiness and the frequency of precipitation. It is believed that the data here presented are sufficient to show the character and to some extent the value of the method employed, and justify a further application to the method of other localities.

The present description is incomplete. Other matters receiving attention are: the distribution of the various kinds of clouds, thunderstorms, the direction of the higher air strata and the seasonal distribution of the elements. The anticyclones are being studied in a similar manner. The results of a more complete survey of the problem will be given in a later paper.

In conclusion the author wishes to acknowledge with gratitude the assistance received from several sources. Mr. J. M. Sherrier, Local Forecaster at Davenport, Ia., has offered helpful suggestions and courteously given access to the records of that station. Through the kindness of Major H. B. Hersey, official in charge, local office, Chicago, Ill., the author was permitted to examine the evening weather maps of that office. Special thanks are due Mr. C. W. L. Johnson, who has given valuable assistance in the statistical work.

WATER SUPPLY CONTROL AT EVANSTON, ILL.

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Whenever a village emerges as a city, it inherits three large sanitary problems, milk supply, water supply and sewage disposal. The difficulty encountered in the solution of these problems depends upon the size and location of the city. In general, it may be said that as a population thickens throughout a country, these problems became more difficult of solution. Their importance to the health of the community is no longer underestimated. It used to be accepted that sickness was more or less of a visitation, to be awaited and endured with patience and fortitude. With the germ theory of disease, and the modern science of Public Health, contagious diseases have been brought to the correct responsibility. This new attitude finds expression in such a statement that "whenever a death occurs from typhoid, someone ought to be hung." When you consider that typhoid bacilli can live no where save in the human intestinal tract for any considerable period of time, the criminal aspects of the spread of this disease are more apparent.

As a society, we have not yet solved our problem of milk supply, else why the annual toll of sickness and death in every city directly traceable to this source? The solution will probably never come so long as milk delivery is in the hands of competition. Too much altruism is called for. Evanston's milk supply is far above the average and an ordinance soon to come before the City Council will make the control still more rigid.

Our local sewage disposal problem is an interesting commentary on "how not to do it." A great drainage canal defaces our outlying districts designed to carry sewage of this and nearby communities down to someone else. State, governmental and international complications point to the inadequacy of this measure as a permanent solution. Complications have moved faster than construction, and the prospects are that this dilution method of sewage disposal for this community will have survived its period of usefulness before it is ever employed.

The City of Evanston believes she has solved her water supply problem, with the completion in June of the new $225,000 filtration plant. Meantime, the city water is rendered safe by chemical sterilization. The steps that have led to these results may not be without interest and a certain moral.

It has been obvious to many for a number of years that the local water supply carries sewage contamination. A mere physical survey of the situation makes this probable. From the south line of the City of Evanston to the north line of the City of Glencoe, thirteen main sewers pour the drainage of a population of 40,000 into Lake Michigan. The Evanston intake lies in 35 feet of water one and a sixteenth miles from the shore. Knowing that typhoid bacilli can live from one day to a week in lake water and with capricious currents at play, a vicious circle is most possible. Chemical and bacteriological tests repeatedly confirm this. Furthermore, before the chemical sterilization of the water, Evanston, with about the same sources of food and milk supply as Chicago, with superior sanitary advantages and a select population, maintained for a number of years a typhoid death rate from two to three times that of Chicago.

COMPARISON OF DEATH RATES FROM TYPHOID PER 100,000 IN EVANSTON AND CHICAGO

Year	Evanston	Chicago
1907	21	17.5
1908	32	15
1909	28	12.5
1910	24	13
1911	28	10.8
1912	13.8	10.5
1913	13.3	10.5

An investigation of a hundred Evanston cases in 1911 showed that 90 per cent of the victims were users of raw city water. The distribution of these cases by months showed a larger number of cases in the winter months. In sanitary science, this is a recognized index of water-borne typhoid. The situation became acute when in November and December, 1911, Evanston, with a population of 30,000, was averaging over a case a day.

At a cost of $750.00, and on short notice, a "Hypo" sterilization plant was installed, December 25th, 1911, at the Pumping Station, and within two weeks, the mild epidemic was checked. Since that time the rate has been maintained near the normal residual typhoid rate for this district. Moreover, our cases now occur mostly in the summer and autumn, the period when vacation typhoid, finger and fly typhoid, etc., are operative. This is borne out by the following chart:

TYPHOID CASES BY THE MONTH—EVANSTON

Year	Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Cases	Total Deaths
1910	7	8	19	4	5	4	4	5	3	3	2	0	69	6
1911	4	1	1	0	3	0	4	2	4	9	22	49	99	7
1912	12	9	2	4	1	2	1	0	5	17	7	4	64	4
1913	0	1	1	1	3	4	2	1	6	8	3	0	30	4

Year	Cases per 100,000	Deaths per 100,000
1910	276	24
1911	396	28
1912	224	13.8
1913	100	13.3

Enteritis is recognized as a disease rather closely associated with a contaminated water supply. The following table summarizes the deaths from this cause for the past seven years.

EVANSTON DEATH RATE PER 100,000

Disease	1907	1908	1909	1910	1911	1912	1913
Enteritis	45	20	52	48	32	12	37

While there is a notable falling off in 1912, there is a return to near former rate from this disease in 1913. This is possibly explained by the fact of a higher mortality rate, especially among infants during the unusually hot summer of 1913. A higher rate with a greater percentage of cases among young children would in itself rather point to food supply as a source of the infection.

It is fully recognized that too much reliance cannot be placed upon statistics gathered from a population of 30,000 people, yet a fair examination of all the data seems to confirm the experience of many large cities in respect to water borne diseases before and after improvement in the water supply.

If Hazen's theorem is correct, namely, that for every death from water borne typhoid, there are three or four deaths from other diseases attributable also to contaminated water, the above improvement in the typhoid rate has still greater significance to the community.

Recognizing the conclusive evidence of sewage contamination of the city water, a bond issue for $200,000 was voted by a large poll in the fall of 1912.

This plant, now near completion, is of the mechanical gravity type equipped with mixing tank, settling basins, six independent two million gallon filter units and two 1¼ million gallon storage reservoirs. It is located just north of the University campus on land given by Northwestern University. The plant is built so as to use the present pumping station, and with the exception of the operating building, will be sodded over and covered with shrubbery.

The "Hypo" Treatment Plant being used in the meantime has been maintained without additional labor and with a cost for chemicals of about 25c per day. The plant consists of a mixing machine for making the "Hypo" into a thin paste with water. The mixer is set so that the overflow drains into two wooden tanks, eight feet in diameter and three and one half feet deep. The mixing and dilution tanks, arranged in pairs and used alternately, drain into a two-inch wrought iron pipe. Power for mixing and stirring the dilution tanks is furnished by a Pelton wheel. The dilution tanks are set about three feet above the floor and are tapped on the sides about two inches in the clear above the bottom, with ¾ inch galvanized iron pipe. The piping leads to an orifice box and is so arranged that the solution can be drawn from either tank or both tanks at once. The orifice box sets on the floor of the well house and feeds into ¾ inch galvanized iron pipes leading to the grids. Below the orifice box, a valve is set and below this valve a T through which a pressure pipe is connected. The grids consist of ¾ inch galvanized iron pipes, Ts and plugs, each lateral pipe having two ¼ inch holes drilled in and placed on the down stream side of the pipe. One grid is placed over the top of the shaft, the other in the 36 inch T at the side of the well. By placing the grids at these points, the water is treated when it enters the well, and has about twenty minutes contact before reaching the suction of the pumps. At present 50 pounds of the chemical are being used with 1,420 gallons of water. After this mixture has been thoroughly stirred in the dilution tanks, it is allowed to stand for at least one hour before being drawn off. Considerable insoluble matter is always present which would otherwise cause stoppage in the orifice box and valves.

Each gallon of the above solution contains .0352 pound of hypochlorite, analyzing 37 per cent available chlorine. From the following formula, the engineer operates his orifice box:

N=No. of gallons pumped per minute.

$\frac{1,000,000}{N}$=M or number of minutes to pump 1,000,000 gallons.

Q=No. of pounds of "hypo" to be added to each 1,000,000 gallons.

$$\frac{Q}{M} = \text{P. or pounds of Hypo to be added each minute.}$$

$$\frac{P}{.0352} = \text{No. of gallons of liquid to be added per minute.}$$

When any considerable variation in the speed of the pumps is noticed by the engineer, he counts the revolutions and determines the pumpage. The number of gallons of solution to be added is then calculated and from a chart furnished by the manufacturers, the orifice box is set.

The amount of chemical used during the past two years has varied from three to ten pounds per million gallons. There has been some complaint of the odor and taste, but the city accepts the situation as a desirable temporary measure.

ON THE CONDITIONS UNDER WHICH THE VEGETABLE MATTER OF THE ILLINOIS COAL BEDS ACCUMULATED

BY T. E. SAVAGE, UNIVERSITY OF ILLINOIS

All students of the subject agree that coal was derived from vegetable material which has undergone imperfect decomposition without free access of air. The complete explanation of the coal beds involves, among other things, an explanation of (1) the method and conditions under which the plant material accumulated; (2) the kinds and proportions of the different plants that contributed the vegetable material; and (3) the physical and chemical changes by which the plant tissues were transformed into coal. The first part of the problem with regard to the method and the conditions under which the vegetable matter of the coal beds accumulated can be studied somewhat independently of the other two, and the solution should be found in the structural features of the coal beds and associated strata.

Two important theories have been proposed to explain the mode of accumulation of the vegetable matter of coal beds. The older of these, known as the "transport of driftage" theory, assumes that the vegetable materials grew on land areas, whence they were carried by streams and deposited in the bodies of water where they accumulated. The other, known as the "swamp, or growth-in-place" theory was suggested in 1778 and assumes that the vegetable matter of coal beds accumulated in swamps practically in the places where the plants grew.

The following facts presented in the principal coal beds of Illinois make impossible the application of any form of the transport theory of accumulation of the vegetable material: (1) the great extent of the coal beds—the Herrin (No. 6), and Springfield (No. 5) beds were deposited in practical continuity over at least 7000 square miles, and probably over a considerably greater area in the state; (2) the regularity of thickness of the coals—the Herrin (No. 6) bed ranges from 7 to 9 feet over a known area of at least 5,000 square miles. A thin band of shale or shaly coal (blue band) one-half to two inches thick, is present 18 to 24 inches above the floor of this coal over practically the entire area of its distribution, and the thickness of the benches above and below the "blue band" is remarkably uniform. The Springfield (No. 5) bed, also scarcely varies one foot in thickness over more than 5,000 square miles. (3) The small percentage of mineral matter or ash in the coal shows that very little mud and sand sediments were mixed with the plant remains as they accumulated.

In time of flood the amount of mud and sand carried by streams is so great compared with the amount of vegetable matter, and the latter is deposited so irregularly, that it can scarcely be imagined how the plant material of these coal beds could have been carried by streams into the Illinois basin, and have accumulated in practical continuity over such extensive areas, in anything like such uniform thickness, and with so little mingling of mineral sediments. Extensive areas of relatively pure vegetable matter are known to be accumulating in swamps at the present time, but there is no known place where plant remains transported by streams during floods are accumulating as a continuous bed over any considerable area, in anything approaching uniformity of thickness, and without a very large mixture of sand and mud; nor does it seem probable that pure transported vegetable deposits have ever accumulated over any considerable area in the past.

From a study of small coal basins of France in recent years Fayol, supported by DeLapparent and other French geologists, has revived the transport theory of accumulation of the vegetable matter of coal beds. However, practically every geologist who has studied extensive coal beds, especially those of the Appalachian region of the United States with which the coal beds of Illinois are comparable, has rejected the transport theory of accumulation as applied to those beds. Rogers

Brothers, Lesquereux, Dawson, Andrews, Dana, Orton, Stevenson, White, and Ashley, have all accepted the growth in place theory of accumulation of the vegetable matter of extensive coal beds as the only one that is consistent with the facts. It is safe to assume, then, that the vegetable matter of the coal beds of Illinois accumulated practically in the places where the plants grew.

The acceptance of the growth-in-place theory of accumulation does not settle the question whether the basins bordered the sea, as lagoons, or occupied broad depressions over coastal plains, as the Dismal Swamp, or covered large areas over river flood plains; nor is it purposed to discuss this phase of the question at this time. The fact that the vegetable matter of coal beds accumulated under water in the places where the plants grew does not prove that the water was ever more than a few inches, or at most a very few feet in depth, even where coal beds 5 to 10 feet thick have been formed. On the contrary the structural features of the coal beds indicate conclusively that the water in which the vegetable matter accumulated was very shallow as well as that it was very quiet.

STRUCTURAL FEATURES OF THE COAL BEDS

One of the more conspicuous structural features of the coal beds of Illinois, which are representative of the larger beds everywhere, is their stratification, the more prominent bedding planes being 3 to 5 or more inches apart. These bedding planes form partings along which the coal separates rather easily, and they usually show well-developed bands of "mother coal," or mineral charcoal. These stratification planes often become more conspicuous when the bed is weathered, but some of them are prominent on unweathered faces. Such a conspicuous clean parting of mineral charcoal occurs 18 to 24 inches below the roof of the Herrin (No. 6) coal over several hundred square miles in western and southern Illinois, and appears to be almost co-extensive with that bed. Along this charcoal zone, the coal separates so perfectly that where the overlying shale does not stand well in the mines the coal above this parting is left for a roof. Five or six inches lower is another mineral charcoal parting, almost equally well developed and persistent.

Between the more prominent partings and bedding planes, the coal from roof to floor is made up of alternating bright and dull laminae, which are usually ½ to 1-32 of an inch thick, although in places they are considerably thicker. The aggregate dull bands generally make up nearly or quite one-half of the coal beds, and they appear to be of the same general nature as the bedding planes mentioned above. They are often rather uniform in thickness over considerable areas, but in places they thicken for some distance and in others they thin down to knife-edge partings. When the coal is split along well developed dull laminae the cleavage planes almost always show distinct mineral charcoal surfaces. The bright laminae appear to be quite homogeneous in structure.

The features above described are not peculiar to Illinois coals. H S. Rogers and others have noted the alternations of laminae of bright and dull coal, and the predominance of mineral charcoal in the dull laminae in the coals of the Appalachian region, and the writer has observed the same characters in the coals of Iowa. They have been described from coal beds generally in different parts of the world. The mineral charcoal is so constantly present, and so intimately mingled in, and constitutes such an important part of the dull laminae of the coal that they must have been developed together; in fact, the dull appearance of these laminae in relatively pure coal beds is due for the most part to the presence of mineral charcoal in these bands.

THE ORIGIN OF "MOTHER COAL" OR MINERAL CHARCOAL

Two main explanations have been proposed to account for the origin of mineral charcoal. One of these, held by many paleobotanists and chemists in recent time, explains the mineral charcoal as formed from real charcoal derived from plant tissues which resulted from forest fires sweeping over land areas, the charred fragments being subsequently swept by flooded streams into the basins where they were deposited with the mass of vegetable matter there in process of accumulation.

This explanation assumes that a considerable part of the vegetable matter of the coal was transported material, which assumption is open to all of the objections to the "transport" theory mentioned above. It assumes that a very important proportion of the coal was derived from plant tissues that had been charred by fires previous to their accumulation, and that these charred fragments had been carried into the coal basin by streams in such enormous quantities as to cover the surface of practically the entire area of the present coal beds, 5000 to 8000 square miles or more in extent; that this process took place not only once but was repeated as many times as there are persistent dull charcoal-bearing laminae; requiring scores or hundreds of recurrences of such charcoal deposition during the accumulation of the vegetable matter of each of the large coal beds. It assumes such a depth of water above the accumulating vegetable matter that the charred fragments brought in by the streams could be freely floated out above the mass of vegetable matter already present, to every part of the basin; and most impossible of all, that the streams that carried such vast quantities of charred vegetable matter carried at the same time little or no mud or mineral sediments. If it is assumed that the water of the basin was so shallow that the clay and sand brought down by the streams were strained out in the meshes of the tangled plant debris near the margin of the swamp, then the same vegetable sieve would catch the charred fragments and not permit them to be distributed to every part of the basin in which the vegetable matter was ac-accumulating. It will be seen that this explanation is not at all in harmony with the facts of the vertical and horizontal distribution of the mineral charcoal bands in the coal beds.

A modification of this view assumes that the mineral charcoal represents partially burned vegetable matter resulting from fires sweeping over the surface of the marshes in which the vegetable matter of the coal beds was accumulating. It is not probable that fires would start from lightning and travel over water-covered swamps with only the living undergrowth and green leaves and branches of the trees to support the flames; and if they did they would not leave such a uniform and thick layer of charred fragments as would be required to form the mineral charcoal that occurs in the well developed dull laminae. If it is assumed that the surface of the vegetable matter that had accumulated in the swamp had been exposed to the atmosphere and partially dried before the fires swept over it; then the general conditions involved would be similar to those under which the mineral charcoal is interpreted as having been formed by the partial atmospheric decay of the upper surface of the vegetable material of the bog exposed during periods of unusual low water, without the action of fires.

It seems to the writer that the explanation of mineral charcoal as resulting from the temporary exposure and partial atmospheric decay at the surface of the vegetable matter in the bog, instead of the assumption that it must have been charred by fire, is much more consistent with the following facts: (1) the frequent repetitions of the dull laminae containing such considerable thicknesses of mineral charcoal; (2) the larger number of plant spores in the dull laminae than in the bright coal; (3) the numerous pinnae and pinnules of ferns[1] in the midst of the mineral charcoal fragments; (4) the absence of layers of ash that would result from the burning of vegetable matter at the surface of the bog; and (5) the changes that take place in the vegetable matter at the surface of shallow marshes during period of drought and exposure at the present time.

EXPLANATION OF THE BRIGHT AND DULL LAMINAE

In explaining the origin of the bright and dull laminae, Dawson[2] maintained that it was only the outer bark of flattened tree trunks that formed the shining coal. In a recent paper on the origin of bright laminae of coal, Pringle[3] of the Geological Survey of Great Britain, reaffirms Dawson's view.

The serious objection to this view is the fact that the bright and dull laminae of the coal beds are so nearly parallel and are often continuous for long distances. Trees that are overturned in swamps fall in various directions, and their trunks lie across one another at different angles. If only the cortical portion of tree trunks formed the bright laminae of coal, these bright laminae would not be continuous for long distances, and the dull laminae would be broken at short intervals by small areas of bright coal representing the cross-sections and oblique sections of the cortical portions of tree trunks that lay at different angles and at different levels from those that formed the bright bands in any exposure.

Microscopic examination of bituminous coal has shown that spores are more numerous in the dull laminae than in the bright, and hence some geologists have concluded that the dull laminae resulted from the greater number of spores in these bands, while the bright laminae were formed from the more woody portions of the plants. However, a study of the dull laminae shows that, while they may contain spores in greater abundance than the bright laminae, yet they are very largely composed of mineral charcoal which certainly has been derived from plant tissues other than spores.

The alternation and great extent of the bright and dull laminae are such constant features of the coal beds, and the mineral charcoal is so generally present in the dull laminae that any adequate explanation of the origin of these features must involve agencies that were repeatedly operative over practically the entire area of accumulation of the coal beds. The only re-

1, White, David; Economic Geology, Vol. III., 1908, p. 302.
2, Dawson, J. W.; On the Conditions of the Deposition of Coal. Quar. Jour. Geol. Soc., Vol. 22, 1866, p. 141.
3, Pringle, John; On the Origin of Bright Laminae of Coal. Trans. Edinburgh Geo.. Soc. Vol. X., pt. 1, 1912, p. 33.

current agency of such widespread action is change in the water level of the basin during the time the vegetable material was accumulating.

If it is assumed that the dull laminae resulted from the flooding of the basin, we should have associated with the dull laminae a considerable percentage of mud deposited during such times of flood. We are not left to speculate with regard to the effects of flooding of a basin during the progress of accumulation of the vegetable matter of the coal, for we have such an example in the clay band or "blue band" of the Herrin (No. 6) coal, which extends over practically the entire area of its distribution, and is clearly a mud parting due to flooding. Black shale partings common in portions of some coal beds, as in coal No. 1, in Illinois are also records of flooding of the marshes during the time of accumulaton of the vegetable matter. The typical dull laminae and mineral charcoal zones in the large coal beds of Illinois, as elsewhere, are not such mud partings. They usually contain only a slightly, if any, greater percentage of ash than the bright bands, and are practically free from clay silt. They contain a relatively smaller percentage of volatile matter and a larger proportion of fixed carbon than the bright bands. It will be seen from the following table, in which a number of proximate analyses of mineral charcoal are compared with analyses of average coal from the same beds, that in general the mineral charcoal contains only a little if any more ash than the average coal of the bed in which it occurs.

After discussing the original amount and the composition of the ash contained in living species of such types of coal plants as lycopods, ferns and equisetae, Stevenson[1] concludes that "one should expect to find in ordinary (pure) coal not much less than 6 per cent of ash, or even more, in which silica and alumina should predominate greatly." He thinks it probable that coals containing less inorganic matter than the plant substance should have yielded, have had some of the original inorganic content removed by solution in ground water. It is probable that some coals which locally contain more than the original amount of inorganic matter, as pyrite lenses, etc., have been situated in places favorable for deposition of minerals rather than solution, and in this way have become enriched in their mineral content. In many places also a small percentage of the inorganic constituents of the coal above that originally present in the plants, may have come from wind-blown dust

1, Stevenson, J. J. The Formation of Coal Beds; Proc. Am. Phil. Society, vol. LII., 1913, p. 107.

Table I.

PROXIMATE ANALYSES OF MINERAL CHARCOAL AND OF AVERAGE COAL FROM THE SAME SEAMS

(a) Charcoal samples; (b) Average.

	Water	Volatile Matter	Fixed Carbon	Ash	Ash in charcoal above or below that in average sample.
1a	1.17	19.77	72.13	6.93	+4.69
1b	1.94	39.26	55.83	2.24	
2a	.75	20.36	71.07	7.82	+3.04
2b	1.37	37.80	54.46	4.78	
3a	2.39	12.40	75.34	9.87	+4.20
3b	1.68	34.97	57.00	5.67	
4a	.52	14.32	64.03	21.13	+3.92
4b	1.04	28.01	49.24	17.21	
5a	.55	9.92	81.37	8.16	—1.97
5b	.85	16.85	69.58	10.13	
6a	.85	8.35	87.64	3.15	—2.18
6b	1.19	20.76	71.70	5.33	
7a	.57	20.98	70.37	8.08	—2.52
7b	.77	17.11	70.74	10.60	
8a	.85	10.49	84.01	4.65	—3.74
8b	.95	17.85	72.15	8.39	
9a	1.58	23.96	64.28	10.18	— .54
8b	.94	17.85	72.15	8.39	

Nos. 1-8. Analyses by McCreath, second Geological Survey of Pennsylvania. Vol. MM, pp. 1-107; Moisture at 225 degrees F.

No. 9, Analyses Ill. Geol. Survey, Herrin (No. 6) coal, Williamson County, Illinois; Moisture air dried.

that settled over the coal basin during the long period of accumulation of the vegetable matter. The amount of ash in a coal bed varies very considerably at different levels and in different places even in the same mine. Among the possible causes of such variation are differences in the proportions of the kinds of plants that formed the coal, removal and deposition of mineral matter by ground water, and wind-blown dust. Hence, in the absence of definite evidence of sediment contributed by water, such as black shale or mud partings, it is thought that, as far as the bearing on the conditions of accumulation of the vegetable matter is concerned, not much significance can be attached to the variation in the amount of ash in a coal bed of a small percentage above or below the original amount that may have come from the plants that formed the coal.

The analyses given in Table I. show that the mineral charcoal contains a smaller percentage of volatile matter and a larger percentage of fixed carbon than the average coal of the same bed. The proximate analyses (Table II.) of the bright and dull laminae of the bituminous coal bed, cited by Pringle[1] indicates that the dull laminae are similar in composition to mineral charcoal, as regards the smaller percentage of volatile matter, and the larger percentage of fixed carbon compared with the bright or the average coal.

TABLE II.

	Water	Volatile Matter	Fixed Carbon	Ash
Dull laminae	1.68	14.71	77.17	6.44
Bright laminae	1.75	31.63	63.96	2.66

Lesquereaux[2] described the changes that occur in the vegetable matter at the surface of swamps during dry periods as follows:

"Wherever the growth of peat in submerged bogs is checked by dryness or other causes, the upper surface of the peat becomes crusted, hardened and transformed into a thin coating quite impervious to the entrance of any kind of foreign matter, and it is upon this hard upper crust that the boggy humus forms, or whenever the land becomes resubmerged, a new peat vegetation begins. In such cases such a crust remains as a parting between two layers of peat."

Von Gumbel in 1883 suggested: "It is very probable that in occasional drying of the swamp, followed by renewal of flooding, lies the explanation of the alternating bright and dull coal bands."

In discussing the progress of putrefaction of the vegetable matter of coal, as described by Renault, David White[3] says that if uninterrupted, the process of putrefaction goes on until all the softer tissues are disintegrated and decomposed, leaving only the most indestructible parts, immersed in a dark subgelatinous, plastic or liquid mass, the fundamental matter. This fundamental matter not only envelops the undestroyed woody matter, but it infiltrates the surviving tissues to a greater or less extent. Where the impregnation is complete, we find dense, glossy, and shining coal. In many instances the impregnation has been imperfect, and sometimes intergrades to a charcoal or "mother coal."

It is thought by the writer that the oft-repeated lowering, probably of only a very few inches, of the water level in the

1. Pringle, John. Trans. Edinburgh Geol. Soc., vol. 10, pt. 1, 1912, p. 33.
2. Lesquereaux, L. Second Geol. Survey of Penna. Ann. Rept. for 1885, p. 118.
3. White, David. Some Problems in the Formation of Coal, Econ. Geology, Vol. 3, 1908, p. 303.

shallow swamps, and the consequent exposure of successive levels of the vegetable matter to the air, is the only adequate explanation that accounts for the extensive bedding planes practically free from clay sediments, the general distribution and alternation of the bright and dull laminae and the large amount of mineral charcoal in the latter, as they occur in the coal beds of Illinois. According to this view the bright laminae resulted from the imperfect putrefaction of the vegetable matter entirely under water, while the dull laminae and mineral charcoal resulted from the partial atmospheric decay previous to the more complete subaqueous putrefaction.

If the above view is correct, the dull laminae and mineral charcoal partings of the coal beds are the records of repeated interruptions of accumulation of the less woody kinds of plant material, during which the surface of the vegetable mass in the swamp was above water and exposed to partial atmospheric decay which resulted in the destruction of the softer parts of the plant tissues, leaving them in an indurated and more or less skeletonized and fibrous condition. On resubmergence these residual portions of the vegetable materials were not so readily impregnated with the fundamental matter of the bog as were those parts of the mass that had not suffered partial atmospheric decay, and hence in the process of bituminization these bands of harder, more skeletonized and so more fibrous vegetable matter became transformed into mineral charcoal. Such periods of arrested growth and accumulation of the more herbaceous and succulent kinds of aquatic plants, due to the exposure of the surface of the vegetable matter of the bog, would be favorable for the accumulation on such a surface of a relatively larger proportion of spores than would be mingled with the vegetable mass during periods of submergence and of normal vegetable growth in the bog. The resistant nature of the spore cases would also permit their better preservation than the ordinary plant tissues during such times of exposure. These conditions would explain the greater abundance of spores in the dull than in the bright laminae of the coal beds. The variation in thickness of the dull laminae is assumed to be due to the unevenness of the surface of the exposed matter in the bog. The relatively smaller percentage of volatile matter, and larger percentage of fixed carbon in the mineral charcoal and dull laminae, would be explained in part by the fact that during the times when the surface of the vegetable mass was above water and exposed to atmospheric decay, the volatile products of decomposition escaped into the air, and probably in part because the material of the dull laminae were not subsequently infiltrated with the liquid hydrocarbons of the bog to the same extent as that of the bright laminae.

The foregoing interpretation of the structural features of the coal beds leads to the following very definite conclusions:

1. That the beginning of vegetable accumulation of the coal beds was in a very shallow swamp.

2. That the swamp deepened so slowly, either by subsidence of the area, or from the gradual building up of the border or outlet by sedimentation, or both, that the plants were able to adjust themselves to the changes, and the accumulation of vegetable matter in a general way kept pace with the increasing depth.

3. That throughout the entire period of accumulation of the coal beds the water of the swamp was so shallow that, during the oft-recurring cycles of drought, successive levels of the vegetable mass were temporarily exposed and so modified by partial atmospheric decay as to result in the formation of the dull mineral charcoal laminae.

4. That the time involved in the accumulation of the vegetable material of a coal bed was the time necessary for the growth of the plants, plus the time recorded in the partial interruptions of normal accumulation, indicated by the dull laminae and charcoal partings of the coal, which would very considerably increase the usual estimate of time required.

CONSTITUTION AND BY-LAWS

Illinois Academy of Science

CONSTITUTION

ARTICLE I. NAME

This Society shall be known as THE ILLINOIS ACADEMY OF SCIENCE.

ARTICLE II. OBJECTS

The objects of the Academy shall be the promotion of scientific research, the diffusion of scientific knowledge and scientific spirit, and the unification of the scientific interests of the State.

ARTICLE III. MEMBERS

The membership of the Academy shall consist of *Active Members, Non-resident Members, Corresponding Members, Life Members and Honorary Members.*

Active Members shall be persons who are interested in scientific work and are residents of the State of Illinois. Each active member shall pay an initiation fee of one dollar and an annual assessment of one dollar.

Non-resident Members shall be persons who have been members of the Academy but have removed from the State. Their duties and privileges shall be the same as those of active members except that they may not hold office.

Corresponding Members shall be such persons actively engaged in scientific research as shall be chosen by the Academy, their duties and privileges to be the same as those of active members, except that they may not hold office and shall be free from all dues.

Life Members shall be active or non-resident members who have paid fees to the amount of twenty dollars. They shall be free from further annual dues.

Honorary Members shall be persons who have rendered distinguished service to science and who are not residents of the State of Illinois. The number shall not exceed twenty at one time. They shall be free from all dues.

For election to any class of membership the candidate's name must be proposed by two members, be approved by a majority of the committee on membership, and receive the assent of three-fourths of the members voting.

All workers in science present at the organization meeting who sign the constitution, upon payment of their initiation fee and their annual dues for 1908 become charter members.

Article IV. Officers

The officers of the Academy shall consist of a President, a Vice-President, a Chairman of each section that may be organized, a Secretary, and a Treasurer. These officers shall be chosen by ballot on recommendation of a nominating committee, at an annual meeting, and shall hold office for one year or until their successors qualify.

They shall perform the duties usually pertaining to their respective offices.

It shall be one of the duties of the President to prepare an address which shall be delivered before the Academy at the annual meeting at which his term of office expires.

The Secretary shall have charge of all the books, collections, and material property belonging to the Academy.

Article V. Council

The Council shall consist of the President, Vice-President, Chairman of each section, Secretary, Treasurer, and the president of the preceding year. To the Council shall be entrusted the management of the affairs of the Academy during the intervals between regular meetings.

Article VI. Standing Committees

The Standing Committees of the Academy shall be a Committee on Publication and a Committee on Membership.

The Committee on Publication shall consist of the President, the Secretary, and a third member chosen annually by the Academy.

The Committee on Membership shall consist of five members chosen annually by the Academy.

Article VII. Meetings

The regular meetings of the Academy shall be held at such time and place as the Council may designate. Special meetings may be called by the Council and shall be called upon written request of twenty members.

Article VIII. Publication

The regular publications of the Academy shall include the transactions of the Academy and such papers as are deemed suitable by the Committee on Publication.

All members shall receive gratis the current issues of the Academy.

Article IX. Affiliation

The Academy may enter into such relations of affiliation with other organizations of appropriate character as may be recommended by the Council and be ordered by a three-fourths vote of the members present at any regular meeting.

Article X. Amendments

This constitution may be amended by a three-fourths vote of the members present at an annual meeting, provided that notice of the desired change has been sent by the Secretary to all members at least twenty days before such meeting.

BY-LAWS

1. The following shall be the regular order of business:
   1. Call to order.
   2. Reports of officers.
   3. Reports of standing committees.
   4. Election of members.
   5. Reports of special committees.
   6. Appointment of special committees.
   7. Unfinished business.
   8. New business.
   9. Election of officers.
   10. Program.

   Adjournment.

II. No meeting of the Academy shall be held without thirty days' previous notice being sent by the Secretary to all members.

III. Fifteen members shall constitute a quorum of the Academy. A majority of the Council shall constitute a quorum of the Council.

IV. No bill against the Academy shall be paid without an order signed by the President and Secretary.

V. Members who shall allow their dues to remain unpaid for three years, having been annually notified of their arrearage by the Treasurer, shall have their names stricken from the roll.

VI. The Secretary shall have charge of the distribution, sale, and exchange of the published transactions of the Academy, under such restrictions as may be imposed by the Council.

VII. The presiding officer shall at each annual meeting appoint a committee of three who shall examine and report in writing upon the account of the Treasurer.

VIII. No paper shall be entitled to a place on the program unless the manuscript or an abstract of the same shall have been previously delivered to the Secretary.

IX. These by-laws may be suspended by a three-fourths vote of the members present at any regular meeting.

List of Members

(Revised May, 1915.)

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Reynolds, Carrie, B.S., Lake View High School, Chicago. (Botany).
Rice, Wm. F., A.M., Wheaton College, Wheaton. (Physics.
*Rich, John L., University of Illinois, Urbana. (Physiography).
Richardson, R. E., Natural History Bldg., Urbana. (Zoology).
Ricker, N. C., D. Arch., University of Illinois, Urbana. (Architecture).
Riddle, Oscar, Cold Springs Harbor, N. Y.
Ridgley ,D. C., State Normal University, Normal. (Geography).
Risley, W. J., B.S., Millikin University, Decatur. (Mathematics).
Roberts, H. L., Cape Girardeau, Mo. (Geography).
Roberts, John M., A.B., 345 N. Michigan Ave., Chicago.
Robinson, C. H., Normal. (Archaeology).
Rolfe, C. W., M.S., University of Illinois, Urbana. (Geology).
Root, Clarence J., U. S. Weather Bureau, Springfield. (Climatology).
Ross, Clarence S., A.B., N. H. Bldg., Urbana. (Geology.)

Salisbury, R. D., LL.D., University of Chicago, Chicago. (Geology).
Sallee, Roy M., Gerlaw. (Agriculture).
Sampson, H. C., University of Chicago, Chicago. (Botany).
Savage, T. E., Ph.D., University of Illinois. (Stratigraphic Geology).
Schlesinger, Hermann L., Ph.D., University of Chicago, Chicago. (Chemistry.)
Schneider, Henry F., A.B., 1825 Spring St., Springfield. (Chemistry).
Schulz, W. F., Ph.D., 926 W. Green St, Urbana. (Physics).
Shamel, C. H., Ph.D., 535 Black Ave., Springfield. (Chemistry)
Shaw, J. B., Sc.D., University of Illinois, Urbana. (Mathematics).
Shaw, L. I., Ph.D., University Club, Evanston. (Chemistry).
Shelford, V. E., University of Illinois, Urbana. (Zoology).
Shinn, Harold B., A.M., 3822 Lowell Ave., Chicago. (Zoology).
*Simpson, Jesse P., M.D., Palmer, Ill. (Medicine).
*Simpson, Q. I., Palmer, Ill. (Eugenics).
Sims, J. P., 851 S. Lincoln Ave., Springfield.
Slocum, A. W., University of Chicago, Chicago.
Smallwood, Miss Mabel E., 550 Surf St., Chicago. (Zoology).
*Smith, C. H., M.E., 5517 Cornell Ave., Chicago. (Ed. *School Science*).
Smith, Frank, A.M., University of Illinois, Urbana. (Zoology).
Smith, Huron H., Field Museum, Chicago. (Dendrology).
Smith, Mrs. H. R., (Taggart), 105 Byers Ave., Akron, Ohio. (Chemistry)
*Smith, Isabel Seymour, M.S., Illinois College, Jacksonville. (Botany).
Smith, Jesse L., Supt. of Schools, Highland Park.
*Smith, L. H., Ph.D., University of Illinois, Urbana. (Chemistry).
Smith, Orrin H., High School, Champaign. (Physics).
Smith, Sidney B., B.S., R. R. No. 9, Springfield. (Farming).
Smith, Wilbur, 5636 Kenmore Ave., Chicago. (Botany).
Snyder, John F., M.D., Virginia. (Archaeology).
Sorgatz, George F., M.D., State House, Springfield. (Medicine).
Southworth, Eva., B.S., 419 College Ave., DeKalb. (Geography).
*Starr, Frederick, Ph.D., University of Chicago, Chicago. (Anthropology).
Stevens, Frank L., Ph.D., University of Illinois, Urbana. (Plant Pathology).
Stevenson, A. L., Principal Lincoln School, 1308 Morse Ave., Chicago.
*Stewart, H. W., University of Illinois, Urbana. (Agronomy).

*Charter Members.

Stieglitz, Julius, Ph.D., University of Chicago, Chicago. (Chemistry).
Stillhamer, A. G., Bloomington. (Physics).
Stoek, H. H., E.M., University of Illinois, Urbana. (Mining Engineering.)
Stowe, Herbert, M.D., 4433 Lake Ave., Chicago. (Medicine).
*Strode, W. S., M.D., Lewiston. (Medicine).
Strong, R. M., Ph.D., University of Chicago, Chicago. (Zoology.)
Swarth, H. S., University of California, Berkeley, Calif.
Sykes, Miss Mabel, B.S., S. Chicago High School, Chicago. (Geology).
Talbot, Marion, LL.D., University of Chicago, Chicago. (Sanitation).
Tandy, M., Dallas City. (Biology).
*Tanquary, M. C., Ph.D., Kansas State Agricultural College, Manhattan, Kansas. (Zoology and Entomology).
Tatnall, Robert R., Ph.D., Syracuse University, New York. (Physics).
Tedesche, Rabbi Sidney S., 452 W. S. Grand Ave., Springfield.
Thompson, David G., B.S., 1629 Hinman Ave., Evanston. (Geology.)
Tiffany, Hanford, State Normal School, Charleston. (Botany).
Tower, W. E., Englewood High School, Chicago.
*Townsend, E. J., Ph.D., University of Illinois, Urbana. (Mathematics).
Transeau, E. N., State Normal School, Charleston. (Botany).
Trapp, A. R., M.D., Ill. Nat'l Bank Bldg., Springfield. (Medical Diagnosis).
Tsou, Y. Hsuwen, Box 78, University Sta., Urbana. (Entomology).
Turton, Chas. M., A.M., 2059 East 72d Place, Chicago. (Physics).
Udden, Anton D., Augustana College, Rock Island. (Physics and Mathematics).
Umbach, L. M., Northwestern College, Naperville. (Botany).
Van Alstine, E.. Experiment Sta., Urbana. (Chemistry).
Vestal, A. G., University of Chicago, Chicago. (Ecology.)
Wager, R. E., State Normal School, DeKalb. (Biology.)
Walton, Calvin L., Ph.D., 4129 N. Hermitage Ave., Chicago. (Zoology).
Ward, H. B., Ph.D., University of Illinois, Urbana. (Zoology, Parasitology.)
Washburn, E. W., Ph.D., University of Illinois, Urbana. (Chemistry).
Waterman, Warren G., A.M., Knox College, Galesburg, (Botany.)
Webb, J. M., U. S. Bureau of Mines, Urbana.
Weber, H. C. P., Ph.D., University of Illinois, Urbana. (Chemistry).
Webster, G. W., M.D., 30 N. Michigan Blvd., Chicago.
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Weller, Annie L., Eastern Illinois State Normal School, Charleston.
*Weller, Stuart, Ph.D., University of Chicago, Chicago. (Paleontology).
Wells, C. C., B.S., 1006 So. Michigan Ave., Chicago. (Chemistry).
Wells, M. M., S.B., University of Chicago, Chicago. (Zoology.)
Westcott, O. S., Waller High School, Chicago.
Whitney, Worallo, Bowen High School, Chicago. (Botany).
Wilczynski, E. J., Ph.D., University of Chicago, Chicago. (Mathematics).
Williston, S. W., M.D., Ph.D., University of Chicago, Chicago. (Paleontology).
Wilson, R. E., Ph.M., 2015 Sherman Ave., Evanston. (Mathematics).
Windsor, Mrs. P. L., 609 Michigan Ave., Urbana (Entomology).
Winslow, Charles A., 2125 Sherman Ave., Evanston. (Geology).
*Winter, S. G., A.M., Illinois Wesleyan, Bloomington. (Histology).
Wirick, C. M., A.M., Crane Technical H. S., Chicago. (Chemistry)
*Wood, F. E., A.B., Wesleyan University, Bloomington. (Zoology).
Woodburn, Wm. L., Northwestern University, Evanston. (Botany).
Woodruff, Frank M., Chicago Acad. of Sci., Chicago. (Taxidermy).
Wright, E. M., Albion. (Aquatic Biology).
Young, Abram Van Epps, 2020 Orrington Ave., Evanston. (Chemistry).
Young, G. B. M.D., 710 City Hall, Chicago. (Sanitation).
Young, Mrs. J. D., B.L., 4752 Vincennes Ave., Chicago. (Biology).
Zelany, Charles, Ph.D., 606 Matthews Ave., Urbana. (Exper. Zoology).
*Zetek, James Ancon, Panama Canal Zone. (Entomology).

*Charter Members.

TRANSACTIONS

OF THE

Illinois Academy of Science

EIGHTH ANNUAL MEETING

Springfield, Ill., Feb. 19 and 20, 1915

VOLUME VIII

1915

PUBLISHED BY THE ACADEMY

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Edited By

A. R. Crook

1915-1916

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OFFICERS AND COMMITTEES FOR 1915-1916

President, U. S. Grant, Northwestern University, Evanston.
Vice-President, E. W. Washburn, University of Illinois, Urbana.
Secretary, A. R. Crook, State Museum, Springfield.
Treasurer, H. S. Pepoon, Lake View High School, Chicago.

The Council

President, Past President, Vice-President, Secretary, and Treasurer

Publication Committee

The President, Secretary, and C. H. Smith, Editor "School Science," 5517 Cornell Ave., Chicago.

Membership Committee

G. D. Fuller, University of Chicago, Chicago.
E. N. Transeau, State Normal School, Charleston.
W. S. Bayley, University of Illinois, Urbana.
L. I. Shaw, Northwestern University, Evanston.
J. S. Compton, Eureka College, Eureka.

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Alice J. Patterson, Normal.
E. O. Jordan, University of Chicago, Chicago.
T. L. Hankinson, State Normal, Charleston.
Thos. E. Lyon, 413 S. W. Grand Ave., Springfield.

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C. G. Hopkins, University of Illinois, Urbana.
E. J. Townsend, University of Illinois, Urbana.
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Ecological Survey Committee

S. A. Forbes, State Entomologist, Urbana.
H. C. Cowles, University of Chicago, Chicago.
T. L. Hankinson, State Normal School, Charleston.
V. E. Shelford, University of Illinois, Urbana.
F. C. Baker, Academy of Science, Chicago.
H. S. Pepoon, Lake View High School, Chicago.
G. D. Fuller, University of Chicago, Chicago.

Secondary Science Committee

Otis W. Caldwell, University of Chicago.
Worallo Whitney, Bowen High School, Chicago.

PAST OFFICERS OF THE ACADEMY

1908

President, T. C. Chamberlin, University of Chicago.
Vice-President, Henry Crew, Northwestern University.
Secretary, A. R. Crook, State Museum of Natural History.
Treasurer, J. C. Hessler, James Millikin University.

1909

President, S. A. Forbes, University of Illinois.
Vice President, John M. Coulter, University of Chicago.
Secretary, A. R. Crook, State Museum of Natural History.
Treasurer, J. C. Hessler, James Millikin University.

1910

President, John M. Coulter, University of Chicago.
Vice-President, R. O. Graham, Illinois Wesleyan University.
Secretary, A. R. Crook, State Museum of Natural History.
Treasurer, J. C. Hessler, James Millikin University.

1911

President, W. A. Noyes, University of Illinois.
Vice-President, J. C. Udden, University of Texas.
Secretary, Frank C. Baker, Chicago Academy of Science.
Treasurer, J. C. Hessler, James Millikin University.

1912

President, Henry Crew, Northwestern University.
Vice-President, A. R. Crook, State Museum of Natural History.
Secretary, Otis W. Caldwell, University of Chicago.
Treasurer, J. C. Hessler, James Millikin University.

1913

President, Frank W. DeWolf, State Geological Survey.
Vice-President, H. S. Pepoon, Lake View High School, Chicago
Secretary, E. N. Transeau, Eastern Illinois Normal School.
Treasurer, J. C. Hessler, James Millikin University.

1914

President, A. R. Crook, State Museum, Springfield.
Vice-President, U. S. Grant, Northwestern University, Evanston.
Secretary, Edgar N. Transeau, Eastern State Normal School, Charleston.
Treasurer, John C. Hessler, James Millikin University, Decatur.

Minutes of the Eighth Annual Meeting

SPRINGFIELD, ILLINOIS, FEBRUARY 19 AND 20, 1915

The meeting was called to order in the lecture room of the State Museum at 2 p. m., Friday, by President A. R. Crook. Mr. Finley Bell of the State Legislature Reference Bureau gave an address of welcome on behalf of the State Government in the absence of the Governor and also extended a cordial invitation to the members of the Academy to visit the newly established Reference Bureau.

The President replied, thanking the speaker for the cordiality of the reception and expressing the interest of the Academy in the welfare of all branches of the State Government.

The reports of the Secretary and the Treasurer were read. (See pages 11 and 13.)

The Calendar Committee, through Dr. A. R. Crook, reported progress in securing the attention of other organizations of scientific and business men in this country and abroad, to the need of an improved calendar. It was moved and passed that the Calendar and the Legislative Committee be continued. The President then appointed the Auditing, Nominating and Resolutions Committees.

The Symposium on Colloids was then presented and a paper read by Dr. Don W. Deal.

At 6 o'clock a banquet given in honor of the Academy by the Springfield Commercial Association was enjoyed at the Leland Hotel. Ex-Governor W. A. Northcott acted as toastmaster. Senator Keller gave an address of welcome to which Professor John M. Coulter responded. One of the features of the banquet was the excellent singing by the Chorus of the Commercial Association.

At 8 o'clock the Academy joined an audience of over two thousand citizens of Springfield at the Armory, to hear an address by Dr. A. L. Day, Director of the Carnegie Geophysical Laboratory, of Washington, D. C., on "Volcanic Emanations." The lecture was illustrated by a remarkable series of photographs of volcanic phenomena displayed by the volcanoes of Hawaii.

At 9 a. m., Saturday, the Academy assembled at the Capitol Building. Two sections were organized; one including the papers in Botany, Bacteriology and Chemistry, under the chairmanship of Professor E. W. Washburn, and one including the papers in Zoology, Entomology and Geology, under the chairmanship of Professor H. B. Ward. In the former section thirteen papers, in the last ten papers, were presented.

The Saturday luncheon was served in the State Museum by a committee of ladies acting for the Springfield members of the Academy and the State Museum.

At 2 p. m. the Academy reassembled in the Senate Chamber. President Crook delivered an address on "The Relation of Academies of Science to the State." Ex-Governor Northcott gave an address on "The Philosophy of Science."

By way of a report for the Committee on Secondary Science, Professor J. C. Hessler read a paper on the "Relation of Chemistry Courses to the High School Domestic Science and Agriculture." On motion of Professor Noyes the Secretary was ordered to forward this paper to "Science" for publication.

Professor S. A. Forbes presented a report for the committee on Ecological Survey.

Dr. H. S. Pepoon offered resolutions concerning a home for the State Academy and the State Museum which were unanimously adopted.

Professor W. S. Bayley notified the Academy of the following proposed changes in the constitution which will be brought up at the next session:

To amend Art. III of the constitution (1) *by striking out the words "corresponding members" and "honorary members" from the first paragraph, and by inserting the word "and" before "life members,"* (2) *by striking out paragraphs* 4 *and* 6 *relating to corresponding members and honorary members.*

It is also recommended that the Executive Committee be instructed to remit the initiation fee for any of the present corresponding and honorary members who may be elected to active membership.

Miss Alice Patterson moved that an effort be made to affect county organizations for the setting aside of plats of natural vegetation in each county, to preserve for future generations some of our native fauna and flora which are now threatened with extinction. The financing of these projects is to be done by securing both local and State aid. On action the matter was referred to the Legislative Committee.

The Auditing Committee, consisting of Professor J. L. Pricer, Professor J. S. Compton and Mr. Neil Lutes, reported that the accounts had been carefully examined and found correct.

The Nominating Committee, Professor Edward Bartow, Chairman, made the following nominations for officers for the ensuing year:

President, Professor U. S. Grant, Northwestern University.

Vice President, Professor E. W. Washburn, University of Illinois.

Secretary, Dr. A. R. Crook, State Museum, Springfield.

Treasurer, Dr. H. S. Pepoon, Lake View High School, Chicago.

Member Publication Committee, Mr. C. H. Smith, Editor School Science, Chicago.

On motion the Secretary cast the ballot, and they were declared elected.

Mr. Frank W. DeWolf, speaking for the members from Urbana, invited the Academy to hold its 1916 meeting at the University of Illinois. The Academy voted to accept this invitation.

On motion the Academy adjourned.

E. N. Transeau, Secretary.

REPORT OF THE SECRETARY

1913-1914

The seventh annual meeting of the Illinois Academy of Science was held at Northwestern University, Evanston, February 20 and 21, 1914, under the presidency of Mr. Frank W. DeWolf, Director of the State Geological Survey.

The program of Friday afternoon included the President's Address on "Recent Investigations of the Mineral Resources of the Country"; an address on "Earth Tides" by Professor A. A. Michelson; an account of the "International Phytogeographical Excursion" by Professor Henry C. Cowles, and an address on "Recent Theories of Fertilization and Parthenogenesis" by Professor Frank R. Lillie.

At 6 p. m. the members enjoyed a banquet in the University Gymnasium as the guests of the University. President Abram W. Harris made a short address of welcome.

Following the banquet the Northwestern Chapter of Sigma Xi gave an informal reception in the Physical Laboratory. A feature of this occasion which was enjoyed by all was the exhibit and demonstration of many new pieces of physical apparatus.

On the Saturday morning following the reports of the various committees the Academy listened to eleven papers by members.

The officers elected for the following year were:

President, Dr. A. R. Crook, State Museum, Springfield.

Vice President, Professor U. S. Grant, Northwestern University, Evanston.

Secretary, Dr. E. N. Transeau, State Normal School, Charleston.

Treasurer, Professor J. C. Hessler, Millikin University, Decatur.

Member Publication Committee, Professor S. A. Forbes, Urbana.

A meeting of the Council was held at Decatur, June 20. 1915. The program for this meeting, and the possibility of publication of the Transactions were discussed. It was decided that in view of the reduction of our income through the cutting off of the appropriation from the State, that the publication of our proceedings should be held over until 1915. The papers read at the Evanston meeting are all in the hands of the Secretary and the manuscript is ready for the printer. Mr. M. I. Reiffel, Chicago, and Professor F. L. Stevens, Urbana, were elected to membership, subject to the approval of the Academy.

The Academy now has an enrollment of three hundred and twelve members, well distributed over the state. Efforts to secure the interest of high school teachers and others in the work of the Academy have been continued by means of letters and circulars. Respectfully submitted,

E. N. Transeau, Secretary.

REPORT OF THE TREASURER

February 19, 1915.

RECEIPTS

Balance on hand February 20, 1914	$235.91
Received from membership fees	273.00
Received from initiation fees	19.00
Received from exchange on checks	.25
Total receipts	$528.16

EXPENDITURES

To the Charleston Courier, printing	$239.75
To the Charleston Plaindealer, printing	17.25
To E. N. Transeau, Secretary	52.92
To the West Paper Co., envelopes	.60
To John C. Hessler, Treasurer	11.48
To Herald Printing & Stationery Co., printing	3.35
To the Barnes-Crosby Co., Chicago	1.07
Total expenditures	$328.42

SUMMARY

Total receipts Feb. 20, 1914, to Feb. 19, 1915	$528.16
Total expeditures for same period	328.42
Balance on hand Feb. 19, 1915	$199.74

JOHN C. HESSLER, Treasurer.

RESOLUTIONS ADOPTED CONCERNING THE STATE MUSEUM AND STATE ACADEMY

Whereas, The State Museum of Natural History contains many collections from the State of Illinois and elsewhere invaluable to the scientific interests of the State; and

Whereas, These collections are housed in wholly inadequate space, and displayed in an unsuitable and antiquated manner; and

Whereas, The State Academy of Science, by its by-laws, meets at intervals in Springfield, and by its work and sympathies necessarily affiliates with the State Museum; and

Whereas, The State of Illinois contemplates the erection at some near date of a commodious structure to house important state departments not now well provided for:

Resolved, By the Illinois State Academy of Science that the Legislature of the State of Illinois be and is earnestly requested to make suitable provisions for the State Museum in the new structure and also provide a definite Springfield home for the State Academy of Science.

H. S. Pepoon, Chairman.

REPORT OF THE RESOLUTIONS COMMITTEE

The Illinois Academy of Science desires to record its deep appreciation of the splendid provision made for its annual meeting at Springfield, which has been one of the most successful it has ever had. The City of Springfield has extended so cordial a welcome and has provided for the Academy so bountifully that the occasion will remain a memorable one in the annals of the organization.

First and foremost, the thanks of the Academy are due to the trustees and staff of the State Museum, each one of whom has contributed by every means in his power to the comfort and convenience of the members present.

To the local committee and to the chairman and workers on the various sub-committees the Academy is indebted for the foresight that has met every need in so satisfactory a manner and has enabled the organization to carry out its program rapidly and effectively.

To Governor Dunne, ex-Governor Northcott, and to many others who rendered special services of great value the Academy desires to express its appreciation for their willingness to add to an already heavily loaded program of duties and to lend material aid in making the Springfield meeting so marked a success.

Finally the Academy feels under lasting obligations to the President and other officers and members of the Springfield Commercial Association, and to the others, especially the singers, who planned and carried out so attractive a social gathering and banquet last evening. The members of the Academy appreciate the opportunity of meeting personally the citizens of Springfield present at the banquet and believe that such personal contact and exchange of ideas will contribute much to the development and progress of the great State of Illinois.

H. B. Ward, Chairman.

REPORT OF THE COMMITTEE ON AN ECOLOGICAL SURVEY OF THE STATE

To the Illinois Academy of Science:

Your Committee on an Ecological Survey reports progress as follows:

In Dr. Cowles's department an interesting ecological study has been made by Mr. F. T. Ullrich on the types of vegetation in a ravine near Chicago as affected by differences of evaporation in the air and different ratios of soil moisture in different parts of the ravine. The aerial evaporation was determined for seventeen stations by the use of a Livingston atmometer, read weekly from July 5 to October 18 (one hundred and twelve days), and the soil moistures were ascertained by the weighing and drying of samples of soil collected weekly from three of these stations at depths of seven and a half centimeters and fifteen centimeters. Mr. Ullrich's paper will be published in the Bulletin of the Illinois State Laboratory of Natural History.

Dr. Shelford has studied the effect upon fishes of the wastes and liquors from the manufacture of illuminating gas, with a view to learning the effect upon fishes and other useful aquatic animals of a contamination of streams. The interesting and important conclusion was reached that fishes, on encountering natural substances commonly found in water as the result of decomposition of organic matter, nearly always react in a way to protect themselves against such contaminations, and thus to preserve the species; but in the case of artificial gas wastes, fishes usually swim into them without turning back in the usual fashion, as if unaware of their noxious quality, even though death may result within a few minutes. This was found true of the gas liquor and also of the principal dissolved gases taken separately. The gas wastes contained many compounds detrimental to fishes, any one of which is dangerous in itself, and no less so in combination with others.

A careful study of the chemical relations of fishes has been made by Mr. M. M. Wells, who has found that Illinois fresh-water fishes are very sensitive to acid and alkaline conditions of the water. Fishes avoid alkaline and neutral waters, and select those slightly acid with carbon dioxide, but avoid waters containing large amounts of acid — conditions particularly detrimental to the young. Mr. Wells has also found that fishes are least resistant to detrimental conditions during the breeding season, some species dying at once when taken from water at this time.

Dr. H. S. Pepoon has been completing his flora of the Chicago area, now practically ready for the printer, and has been working up also his plant collections from the driftless area in northwestern Illinois, in which he has found many new forms and extensions of plant localities. His Jo Daviess county list now contains nearly a thousand species, several of which are not found in Gray's Manual.

Mr. F. C. Baker has continued his studies of the ecological features of the basin of the glacial Lake Michigan. Shallow-water and deep-water faunas have been found in the new Calumet-Sag Channel, now under construction. A section thirty feet deep near Worth shows the same fauna which was observed by Baker in the North Shore Channel at Bowmanville, as reported in Volume IV of the Academy Transactions. A Unio species especially charactceristic, *Unio crassideus,* was present in great numbers. Mr. Baker finds evidence that a rich Unio fauna migrated up the Des Plaines during the Calumet stage and became well established by the time the water had lowered to the Toleston level. The fauna of the Algonquin and Nipissing stations is large and varied, the species represented indicating the fluctuations in depth as the level of the water rose and fell. A report covering the life of the Pleistocene, as recorded in both post-glacial and inter-glacial deposits, is now nearly finished and ready for publication.

The ecological work of the Illinois State Laboratory of Natural History has been substantially in continuance and verification of the Illinois River work of 1914, special attention being paid, however, to collections of the stomachs of fishes for an elaborate study of the food of different species in different situations. Materials were also collected for food studies of aquatic invertebrates living on the bottom. Many dredge collections were obtained from the Illinois River and connected lakes; and a special biological examination of Fox

River was made from Aurora to Elgin, with extensions to neighboring points. Respectfully submitted,

STEPHEN A. FORBES.

REPORT ON THE RELATION OF CHEMISTRY COURSES TO APPLIED SCIENCES OF THE MODERN HIGH SCHOOL

The purpose of the committee that I represent is, I suppose, to bring to the amateur and professional specialists who make up the greater part of the Academy the "new word" regarding high school science. The Academy first gave official recognition to the high schools a few years ago, when it appointed a committee to report upon the organization of the sciences in the high schools and upon the correlation that was being attempted between the pure and applied sciences. The committee's report was of a comprehensive character, and was presented to the 1912 meeting by the chairman, Mr. Worrallo Whitney. Last year the committee's report was upon general science in the high school. This year the chairman has asked me to speak briefly upon chemistry in its relation to the newer, special courses, such as agriculture and domestic science. The situation of physics is so closely related to that of chemistry that I shall consider both more or less together, without making any great distinction between them.

How is chemistry teaching being affected by the presence of agriculture and domestic science in the curriculum? If we are truthful we shall admit that the effect varies all the way from a maximum to zero. At one extreme are the schools, happily few, in which the chemistry that does not lead to applied science is not tolerated at all; at the other extreme sits, in serenity, the classical chemist, who has worked out his scheme of logic from the chemical point of view, and proposes to teach that and nothing else, though the heavens fall. Between these extremes there is the great body of chemistry teachers, men and women who are seeking to teach the fundamental things of the pure science, and yet are willing and ready to draw their illustrations from the newer materials of the applied science.

What about agriculture and domestic science as the exclusive sciences of the high schools? Unless I am greatly mistaken, the calm afterview has brought, or will soon bring, a realization of the limitations that are necessarily inherent in the teaching of special sciences to young people. Experience is teaching us that the study of scientific agriculture and household economics cannot be made particularly stimulating or permanently helpful unless there is a basis of the physical sciences, taught as such, and not as mere illustrations of some special science. This means, of course, that the many children who leave school early in the course cannot get technical agriculture and domestic science. But this cannot be helped. The problem is the old one of the development of courses. We want all children to have American history, but in the nature of things little history can be given, even in a simple way, until the child is ready for it. How little that is, all of us are too painfully aware. We want all college students to have some philosophy, but we cannot give it with any effect before history, science and mathematics have had an opportunity to do their enlarging work. So it is with agriculture and domestic science, subjects which, more than other studies, bring about the application of science to daily life. Each generation gives into the hand of the young agriculturist the use and the care of his soil. The schools cannot help him much if they do not let him see the science upon which permanent agriculture rests, but teach him only the jargon of a trade. Likewise with domestic science. We cannot impart a much higher conception of housekeeping and homemaking if we do not give the deeper, fundamental view that comes from a speaking acquaintance, at least, with chemistry and physics, and I may add, with biology.

This brings us to a consideration of the position of physics and chemistry in the high school course. As you know, these sciences are usually taught in the last two years. As a result, the agriculture and domestic science courses that come in the earlier years do not have any foundational work in the physical science. Evidently, then, the school must either put chemistry and physics into the first years of the high school, or it must offer, in these first years, an elementary physical science that shall serve as a basis for agriculture and domestic science, and for biology as well. This report of mine may be more of a prophecy than a chronicle, and a statement of what should be rather than of what is, but it seems to me that the conditions of modern life will compel us to put two kinds of physico-chemical science into the high school. One of these will be a course that comes early, is elementary, dispenses with theory and equation, and aims to open the student's eyes, to give him a vocabulary, and to set him into connection with the world about him. If the "six and six" plan of division of the high school and the grammar school comes into vogue, this elementary course may go into the eighth year instead of the ninth. This course will not be closely correlated with agriculture and domestic science. The other course in chemistry or physics will be the formal course of the third or fourth high school year. This need not be a more difficult course than the present one, but it should be far richer. It should give not only the logical and quantitative concepts of the master minds of chemical and physical science, but should be correlated with the real agricultural and domestic science of the upper years of the course.

It is a curious fact that the order of the science studies of high schools has changed little, fundamentally, for a generation, and this in spite of the fact that the period named has witnessed the introduction of the laboratory method into secondary instruction. Thus, thirty years ago the science course in the Chicago high schools was, I believe, about as follows:

First Year—Physical Geography and Physiology, one-half year each.

Second Year—Zoology and Botany, one-half year each.

Third Year—Chemistry, one year; Physics, one year.

Fourth Year—Geology and Astronomy, one-half year each.

At the present time the standard course in the same schools is essentially the same, the only prominent change being in the omission of geology and astronomy from the fourth year, and the putting of physics into their place. There is certainly one thing to be said in favor of this older course, even though it offered no laboratory work: Every one going through the high school took the *five* years of science work, whereas today far too many avoid the greater part of the course altogether.

One question more will be suggested in this report: What kind of a teacher is needed for the elementary physical science of the early years of the high school and for the course correlated with agriculture and domestic science in the later years? For, be it known, you can correlate the pure and the applied sciences far more easily than you can "correlate" the teacher. The principal of one of the largest high schools of the State told me not long ago that he had given up hope of getting from his chemistry teachers a proper chemistry course for the domestic science girls of the school. The teachers were well prepared for their work, but they simply could not adapt their knowledge to the needs of the domestic science students. What he was seeking was a woman who had a thorough knowledge of chemistry and also of domestic science, and who had made, as a part of her own education, the needed correlation between the two. This brings me to the fundamental fact in the high school situation in Illinois, as all roads lead to Rome, viz., that the public is, as yet, more willing to put up buildings, and to equip laboratories, miniature experiment stations, and domestic science kitchens than it is to demand and to pay for competent teaching. Is it out of place for me to suggest to the members of the Academy that each of them can do no greater service to the cause of science in this State than to study and to seek to improve, if possible, the high school science instruction in his own community?

John C. Hessler,
Chairman Committee on High School Science.

MEMBERS ELECTED AT THE 1915 MEETING

Miss Frances D. Abbot, 523 S. Glenwood, Springfield. (Botany.)
Mr. S. O. Andros, Urbana. (Geology).
Dr. C. M. Bowcock, Springfield. (Medicine).
Dr. Jessie Y. Cann, 1010-2 California St., Urbana. (Chemistry.)
Mr. H. P. Corson, Urbana. (Chemistry.)
Dr. William Crocker, University of Chicago, Chicago. (Botany).
Mr. W. P. Flint, 1231 W. Edwards, Springfield. (Entomology).
Miss Glen Griggs, 223 S. Madison, Clinton. (Biology).
Professor Wm. H. Haas, Northwestern University, Evanston. (Geography).
Dr. Charles F. Harmon, 318 S. 6th, Springfield. (Medicine).
Mr. M. E. Hinds, M.S., 116 Chem. Bldg., Urbana. (Bacteriology).
A. W. Homberger, Ph.D., Bloomington (Chemistry).
Geo. T. Johnson, 623 Black Ave., Springfield. (Astronomy).
Mr. Fred S. Kay, State Geological Survey, Urbana. (Geology).
Dr. George N. Kreider, 522 Capitol Ave., Springfield. (Surgery).
Mr. George Langford, Supt. Steel Mills, Joliet. (Paleontology).
Dr. Frances Lowater, Rockford College, Rockford. (Physics).
Dr. I. W. Metz, S. Grand Ave., Springfield. (Medicine).
Mr. F. W. Mohiwan, M.S., 116 Chem. Bldg., Urbana. (Chemistry).
Mr. Norman F. Nelson, 1020 N. Main St., Rockford. (Botany).
Mr. H. L. Olin, University of Illinois, Urbana. (Chemistry.)
Geo. Pasfield, M.D., Pasfield and Jackson, Springfield. (Medicine).
J. E. Pogue, Ph.D., Evanston. (Mineralogy).
Mr. W. J. Risley, B.S., Millikin University, Decatur. (Mathematics).
Mr. C. H. Robinson, Normal. (Archaeology).
Mr. Clarence N. Ross, University of Illinois, Urbana. (Geology).

Mr. Henry F. Schneider, 1825 S. Spring, Springfield. (Geology.)
A. R. Trapp, M.D., Springfield. (Med. Diag..)
Charles H. Shammel, Ph.D., 535 Black Ave., Springfield. (Geology).
H. C. P. Weber, Ph.D., University of Illinois, Urbana. (Chemistry).
Professor F. L. Stevens, University of Illinois, Urbana. (Botany).
Mr. M. I. Reiffel, Chicago. (Botany).
Illinois State Library, Springfield.
Miss Mildred Weigley, 419 College Ave., DeKalb. (Household Science).
Miss Eva Southworth, 419 College Ave., DeKalb. (Geography).
Robert C. Lanphier, Sangamon Electric Co., Springfield. (Electrical Engineering.)

Addresses

ADDRESS OF WELCOME

Senator Kent E. Keller in welcoming the Academy to Springfield called attention to the progress of the State from the time of the early settlers to the present and showed how this progress was the result of great natural resources utilized by inquiring, thoughtful and energetic men. The spirit of inquiry which is the scientific spirit is the greatest element in all progress. Men of science are the State's chief asset.

RESPONSE

JOHN M. COULTER

In behalf of the State Academy, I wish to express our appreciation of the hospitality of the Commercial Club, and also of the greetings extended to us by the official representatives of the State.

The three groups represented here tonight are significant. They are the State, business, and science, each in its own way serving this great commonwealth.

The mission of science, as represented by this Academy, is twofold. In the first place, it works through its teachers in developing the scientific attitude of mind in coming citizens. This attitude is fundamental in a self-governing people, for it is one that demands the facts; that knows how to recognize facts; and that distinguishes between demagoguery and real service.

As this spirit becomes dominant, the State will advance from politics from the standpoint of selfish interest, to politics from the standpoint of public service. In the second place, science works for the State through its investigators, whose researches not only uncover our resources, but also suggest the best way of developing them. In a great agricultural State, for example, nothing is more fundamental than the modern work of investigation in plant-breeding, which bids fair to revolutionize our methods and enormously multiply our products. This combined service in improving citizenship and in increasing output, should be encouraged in every possible way.

The mission of business needs no explanation in this presence. It lays hold of our material opportunities and makes the most of them. In developing its own strength, it is in a position to strengthen everything that contributes to the general welfare. It should remember, however, that it is undergirded by science; that it is the results of investigators that bring the suggestions to practical men, who transform them into the terms of public service.

The mission of the State is to conserve and stimulate all those agencies which make for strength and progress. It is right that legitimate business shall be safeguarded and encouraged. It is fundamental that science shall be fostered, both in its teaching phase and in its research phase, for it makes for intelligent citizenship and material progress; and there is no agency through which science in the state can be stimulated so effectively as through the State Academy. It is here that teachers and investigators meet, and from such meetings teachers return to do better teaching, and investigators to do better investigating. To maintain such an agency, therefore, is one of the great opportunities of the state, for no investment will bring larger returns.

THE PHILOSOPHY OF SCIENCE

Ex-Governor W. A. Northcott
Springfield, Ill.

Things must be thought out before they are wrought out. Science is the thought of things and art is the doing of things. The architect first thinks out the great building that the artisan afterwards creates. The sculptor first sees in the rough marble the beautiful creation he afterwards gives to the world. The battle is first thought out by the general before it is fought out by the soldiers. The long-headed man, before the beginning of a great undertaking, in his mind cancels all difficulties and in the performance there is no wasted effort. Science is the triumph of mind over matter.

Science has made more rapid strides in the last one hundred years than in all the world's preceding history. "Close behind the worshipers of knowledge have followed the magicians of today; chemists, engineers and electricians. At their command the spirits of air, water, earth and fire have been made to do man's every bidding. They propel his steamships, railway cars, and mighty engines; they make his garments; they build his houses; they illuminate his cities; they harvest his crops. For him they make ice in the tropics or grow oranges amid snow. For him they fan a heated atmosphere into cooling breezes or banish icy winds. They flash his news around the globe; they carry the sound of his voice for thousands of miles, or preserve it after he is dead. Verily the fairies and genii of old did not so much for Solomon in all his glory."

Science has followed closely on the dreams of the poet and made them realities. Many years ago Tennyson said:

"Here about the beach I wander'd, nourishing a youth sublime
With the fairy tales of science, and the long result of Time;
When the centuries behind me like a fruitful land reposed;
When I clung to all the present for the promise that it closed.

When I dipt into the future far as human eye could see;
Saw the Vision of the world, and all the wonder that would be.—"

"Saw the heavens fill with commerce, argosies of magic sails,
Pilots of the purple twilight, dropping down with costly bales;
Heard the heavens fill with shouting, and there rain'd a ghostly dew,
From the nations' airy navies grappling in the central blue;

Far along the world-wide whisper of the southwind rushing warm,
With the standards of the peoples plunging thro' the thunder-storm;

Till the war-drum throbb'd no longer, and the battle-flags were furl'd
In the Parliament of man, the Federation of the world.

There the common sense of most shall hold a fretful realm in awe,
And the kindly earth shall slumber, lapt in universal law."

The dream of Tennyson is a reality of today and many European cities now with dread see "the nation's airy navies grappling in the central blue."

The submarine that can go a thousand miles under the water and with deadly blow destroy the strongest warships; the armored automobile; the cannon that will carry twenty-five miles, are all creatures of the giant—science that has come to rule the material world.

Said one Irishman to another: "Mike, I see they are sending telegrams now without any poles or any wires." "Yes," replied Pat, "and pretty soon we will be able to travel without leaving home." This is about true today. Seated in the halls of our home town, the moving pictures take us to the most extended corner of the globe and we become conversant with the lives among the antipodes. The phonograph preserves the voice, and the picture galleries of ancestors in the future will not only give the face but the movements and the voice, and man will become practically immortal.

There is an account of a man employed in the Patent Office who wrote to a friend he was going to resign because it was only a temporary job. That the patents would all soon be exhausted and there would be no more business for the department. This letter was written in 1837, and since that time millions of inventions have been patented and there are millions more to come. This man made a bad guess.

It is impossible here to review all of the great strides made by science in the last hundred years and we pause to ask with John Ruskin, "Does the making of costly fabrics and the traveling of many miles an hour make us any wiser or happier?" Do these great scientific inventions make us get anything out of nature's establishment any cheaper? If we want to be strong we have to work. If we want to be wise we have to read and think. If you want to be happy you have to love your fellow man. Nature has no bargain counter and there is no loyal road to any place worth going to. The scientific inventions improve the material conditions of mankind but they are not going to cheat nature out of anything. Huxley once said:

"If I understand the matter at all, Science and Art are the obverse and reverse of Nature's medal, the one expressing the eternal order of things in terms of feeling, the other in terms of thought. When men no longer love or hate; when suffering ceases to cause pity and the tale of great deeds causes no thrill, when the lily of the field shall seem no longer more beautifully arrayed than Solomon in all his glory, and the awe has vanished from the snow-capped peak and deep ravine, then and not until then will Science supplant Nature."

We are not going to get any happiness out of this world in any way different from the way in which our fathers did. The science of the mind does not take the place of the heart. An eminent writer states the case very strongly:

"There is the poetry of life itself, more potent than anything in books can be. Nor need one search for it. The sunlight of a dawn slanting through your window; the twittering of birds in the tree-top; the dandelions in the grass; children romping in the park; the wistfulness in the eyes of your own little boy and girl; the sight of two lovers at a trysting place; the quiet happiness and understanding of the old couple at their golden wedding; the friend whom you salute at the street corner; fellow-workers content in their daily routine; the soaring lines of the skyscraper or the lonely sycamore; the ceaseless pulsing of the city street or the hush and winter calmness of a country hill-side; the farmer among his stock or the sailor in the rigging; the cry of the wind and the swirl of snowflakes; the calm fire-side at home and the rustle and leap of its flames; night and the eternal stars—these make the poetry of life, given to all, and transcending all else."

Knowledge is power. It gave liberty to Greece and glory to Rome. Science is knowledge and adds to the power of man. Whether this knowledge is a blessing or a curse, depends upon how it is used. In the hands of a bad man, it makes him only the stronger for evil; in the hands of a good man it makes him stronger for good. In the last analysis it is a question of added power and not necessarily of added good. The steam adds power to the engine, but unless there is an intelligent hand at the throttle it becomes an engine of destruction instead of usefulness. It has been said that the ignorant expert is better than the learned fool, but is not a learned expert better than either? Science in the correct theory proves useless unless applied to correct practice. Good practice on bad theory is just as useless. The ideal condition is the combination of correct theory with correct art and character makes it serve good purposes. Some fear is expressed that science may conflict with the teachings of the Church. On this subject, thirty years ago, Mr. Rice said:

"The Church has learned wisdom. The persecution of Galileo is not likely to be repeated. And Science too has learned something. In all its wealth of discovery, it recognizes more clearly than ever before the fathomless abysses of the unknown and unknowable. It stands with unsandaled feet in the presence of mysteries that transcend human thought. Religion never so tolerant. Science never so reverent. Nearer than ever before seems the time when all souls that are loyal to truth and goodness shall find fellowship in freedom of faith and fellowship of love."

THE PRESIDENT'S ADDRESS—THE RELATION OF ACADEMIES OF SCIENCE TO THE STATE.

A. R. Crook, Springfield, Ill.

The Illinois State Academy is *true to type* as defined in Brittania, which says:

"An academy of science is a society whose object is the cultivation and the promotion of science undertaken for the pure love of these pursuits with no interested motive."

It thus differs from many organizations whose motive is profit of a pecuniary character for the members. In our organization the motive is the promotion of research and the diffusion of scientific knowledge for the advantage of the people of the State.

Membership in the Academy does not convey distinction. Any one of reputable character who is genuinely interested in science is welcomed as a member. Fortunately the most prominent of our men of science are active members of the Academy, but high school boys are welcomed just as cordially—they are the eminent men of science of the future. The Academy is not exclusive or aristocratic. On the contrary, it is genuinely democratic.

As one meets man after man of our membership he finds an interesting company. They may be connected with an educational institution or not. They have usually the charm of individuality. For example, there is Mr. F., one of the most successful collectors of shells in the United States, who has a remarkable collection of snail shells which he has brought together in a search extending from Maine to Oregon and from Arizona to Florida. A few weeks ago the conchologist of the Philadelphia Academy of Science said to me: "Mr. F. has a remarkable faculty of finding the shells in which we are interested. When in the field he seems to go directly to the pile under which the shells are hidden while I wander around in vain."

Another interesting member of the Academy works in a steel mill. A few years ago when his left hand was caught in the cogs of a wheel he had sufficient quickness, strength and courage to throw his arm around a pillar and to hold until his left arm was torn from the body and his life was saved. In spite of this affliction he has done remarkable work in paleontological collecting. Equipped with the kind of hammer dentists use he has carefully and patiently chipped out very delicate fossils. He has one of the most complete collections of mastodon tusks and teeth which I have seen outside of a public museum.

Another interesting member—just to mention one of the many men connected with educational institutions—has the habit of picking up medals! He is the second man in the United States to receive the Copley Medal given by the English government (the first being Benjamin Franklin). A few years ago he received the Nobel Prize for the best contribution in physics—the only Illinoisan thus far to receive this prize. We are hoping that each member of the academy will take his turn at this prize.

What the relationship between the Academy and the State should be can best be determined by comparing past and present practice in this regard and by conceding the services which each may render the other.

Not until recently did I happen to notice that Alexander the Great gave to the Academy of Aristotle at Athens, 800 talents —a large sum of money—and sent men to distant countries to collect plants, animals and oter natural history objects. The result of this was the production of the best natural history of those times.

The first Ptolemy founded the Academy of Alexandria, housed it in a palace, supplied it with instruments, natural history objects and books. Its library of 700,000 volumes was the most famous of antiquity. In its walls studied Euclid, the father of geometry; Archimedes, the mathematician, who invented the spiral screw used to raise the waters of the Nile for irrigation; and Eratosthenes, who studied the elevation of lands, measured the circumference of the earth and pursued other geological and astronomical subjects. For seven hundred years this academy with its library and museum, was the center of learning for all Africa and Europe.

Italy has had many academies. They were supported by such rulers as the Medici, and by Prince Fredrico Cesi, who founded and supported the Academia of Lincei in 1603—the oldest of the Italian academies and the one to which that famous academician, who was the subject of a charming address by one of our presidents, Galileo, belonged.

Every European country in fact has one or more state academies of science. Just to mention a few of the most prominent we may note the English Academy, the Royal Society, which was founded in 1662 by Charles II. Four years later Louis XIV started the French Academy. Thirty-four years later (1700) Frederick I started the Berlin Academy with its libraries, museums, and laboratories. A magnificent new building was, before the outbreak of the war, being erected for it in Berlin. Twenty-four years later (1724) Peter the Great inaugurated the Petrograd Imperial Academy. Then came the Copenhagen Royal Academy founded by Christian VI (1744); the Hungarian Royal Academy, which now has such fine buildings, museums, etc., founded by Count Szechenyi,; and the Vienna Royal Academy, founded by Ferdinand I. All these rulers, from Alexander the Great to Ferdinand, were men of unusual sagacity and character and nothing which they did was more wise or more instrumental in perpetuating their fame than the foundation of these academies which were centers of the intellectual life of their times. The academies mentioned are provided with ample quarters, with libraries, with museums and with laboratories.

The buildings which they occupy make an imposing array—sometimes being old palaces rich with historical settings, sometimes exquisite new buildings fitted especially for the needs of the institutions.

Their libraries are often remarkable repositories of scientific literature; their museums contain extensive and valuable collections; and their laboratories are in many instances well fitted for scientific investigations.

The list of their members includes men who have made contributions to knowledge which are immeasurable in value.

In the French Academy were such men as La Place, Buffon, Lagrange, D'Alembert, Lavoisier, Fresnel, Ampere, Biot, Gay Lussac, Cuvier, Pasteur; in the Royal Society, Newton, Sir Humphrey Davy, Michael Faraday, Huggins, Lord Lister. These men met in their academies, announced their discoveries, performed their experiments, received criticism, listened to discussions, gave and received inspiration and stimulus. As a result men are today wiser, better and richer.

In return for the $20,000, which the Royal Society receives annually to aid its investigations, it has done much valuable work for the state. It has been called upon in hundreds of instances to furnish expert knowledge and advice. It has been consulted by the English government in a multitude of cases of which the following are instances: The equipment of the Royal Observatory; the question of calendar reform (the very question which our own State academy is considering at present); measurements of various kinds—the length of a degree of latitude, of the seconds pendulum, of standards of length; all kinds of surveys; expeditions to various parts of the world; questions having to do with health and sickness, malaria, tropical diseases, sleeping sickness, etc. Today it stands as the venerated head of the splendid body of British Science.

Coming nearer home, our National Academy, of which many of our Illinois men are members, was incorporated with the provision that it should, "Whenever called upon by any department of the United States government, investigate, examine, experiment and report upon any subject of science or art." In return it receives support from the Federal Government.

Indiana on our east, Michigan and Wisconsin on the north, Iowa, Kansas and Nebraska on the west, all assist their academies financially. We trust that the time is now present when the State of Illinois will do likewise for this association of men who are working in every part of the scientific field for the benefit of our citizens.

In return for State aid what could the Academy offer? Consisting as it does of experts in all departments of science it could most appropriately and safely be made a legislative reference bureau of the highest type for certain things, and in a short time could more than justify its existence by expert advice. We believe that much faulty legislation is enacted. Far too often we are locking the stable after the horse is stolen. Faulty legislation may occur here, as it did in Pennsylvania in 1885, when the legislature authorized counties to pay bounties for the scalps of hawks and owls. Within a short time $90,000 was paid out in bounties. It is estimated that for every dollar saved $1,205 was paid out. The balance of nature was destroyed and within two years after the passage of the bill the farmers found their crops and orchards so completely overrun by destructive mice, rats and insects that it was estimated that $2,000,000 loss was suffered in valuable crops. California had a similar experience.

We may become accustomed, and hence able, to endure unwise legislation, but this should be avoided when among our citizens, there are those wise enough to furnish proper counsel.

Even more important than advice in matters of legislation is the promotion and diffusion of scientific knowledge among the people. Industrial research, agricultural research, medical research, all contain possibilities undreamed of by people who are not so situated as to be conversant with what these lines of investigation have to offer.

The work of chemists, physicists, geologists, biologists and bacteriologists has revolutionized our mode of life, the comforts of our homes, the health and the happiness of our people.

In fact it may be said that every great advance of mankind has been due to scientific researches and their practical application, and I believe that the State can do nothing better to advance the welfare of its people than to encourage such organizations as this Academy of Science, which aims to inspire and assist all men who are working in scientific fields.

May the time soon come when our Academy is found in an appropriate building; is equipped with a library rich in the literatures of science, as applied to Illinois conditions, and with a museum which will fittingly represent man and nature in this State.

ABSTRACT—"VOLCANIC EMANATIONS"

Arthur L. Day, Carnegie Institute, Washington.

This address was chiefly concerned with the identification of and the reactions between the gaseous ingredients set free by the liquid lava at Kilauea during the summer of 1912. A successful attempt was made to collect the gases directly from the liquid lava at a temperature of about 1000° before they reached the atmosphere. The collection of volcanic gases before they have become altered by combustion with air has proved to be an insurmountable difficulty hitherto, whether the gases were collected in tubes for analysis in the laboratory or studied at the point of emergency with the spectroscope. In either case, the gases were burned or were in process of combustion, and therefore could not reveal either their true identity or the original relationships below the surface. This was the first time that unaltered volcanic gases had ever been obtained for study.

In so far as the present reconnaissance yields final results, it shows that the gases evolved from the hot lava at the Halemaumau crater are N_2, H_2O, CO_2, CO, SO_2, free H, and free S; with Cl, F, and perhaps NH_2 in comparatively insignificant quantity. No argon was found, nor any of the other rare gases.

The chief conclusion, upon finding this group of gases in association at 1000° or higher, is that they cannot be in equilibrium at that temperature and must be in process of active reaction among themselves; there can be no equilibrium, for example, between free sulphur and CO_2, nor between hydrogen and SO_2 or CO_2.

This is a conclusion of rather far-reaching consequence, for it must mean that the relative proportions of the gases are constantly in process of local change—a fact which is supported by the very considerable differences between the analyses of the gases contained in different tubes which were filled at the same time. Since these reactions are strongly exothermic, it also follows that a very large and constantly increasing amount of heat is set free during the rise of the gases to the surface. In support of this view it was also observed that when the quantity of gas set free was large, the temperature of the liquid lava in the basin was higher (July 6, 1912, 1185°); when the amount of discharged gas was small it was lower (June 13, 1912, 1070°), the quantity of lava in the basin remaining substantially the same.

Controverting a view recently put forth, H_2O was found to be present as such among the gases set free as, indeed it inevitably must be, for it has long been known that free hydrogen in association with SO_2 and CO_2 will react to form water at these temperatures.

Neither hydrocarbons nor chlorine in appreciable quantities were found.

RECENT DEVELOPMENTS IN SURGERY

Don W. Deal, Springfield, Ill.

One cannot enter upon the discussion of the recent developments of surgery without coming at once upon the part which animal experimentation has played in the reduction of human mortality.

There has been a great deal said and written on this subject—much which is sane and sound and much which is hysterical and sentimental. Medical men and scientific workers are not in any sense unmindful of the sufferings of lower animals and, in animal experimentation, pain is reduced to the minimum or eliminated altogether. In fact, it has seemed to me that scientific investigators hold these animals in higher regard—that they are appreciative of what these animals contribute to science—that they are kinder and gentler in handling them than would be many of the heart-throbbing sentimentalists.

These sentimentalists do not speak of "animal experimentation." They prefer to talk of "vivisection" which has a distressingly quivery sound like the tremulo of the fiddle in the murder scene of a melodrama. They like to picture the eminent scientist as a hairy armed and bewhiskered individual in a blood-stained white gown, gouging at a bound-down pup with a hot poker for no higher reason than that of gratifying his curiosity as to how burning human flesh may smell.

Without detracting in the least from the glories of modern war, it seems to me that, if a dog were consulted he would gladly risk his life for the purpose of saving the lives of countless human beings. I believe this because his more intelligent human brother gladly surrenders his life, in aeroplane and submarine, for no more laudable purpose than that of depriving of life his fellows against whom he has no personal grievance.

Without experimental work with animals no scientific advance would have been possible, unless human subjects were substituted for guinea pigs in experimental work. Bed-side observations alone would not have accomplished appreciable results. They would have left us at the period of crude guess in medicine where "what's good for measles?" was the type of scientific problem which puzzled doctor's heads.

I am going to take this opportunity to criticise the people who derive a lot of self-satisfied altruism by exaggerating the discomforts of animals that are being studied.

A pamphlet recently distributed by anti-vivisectionists, calls the Rockefeller Institute, "Hell at Close Range." The anti-vivisectionists disregard all pain save that which meets with their opprobium and enables them to indulge in their favorite epithets. They strongly condemn the one justifiable pain in the world—the pain associated with the noblest of all objects—the prevention of future pain and saving of human lives.

If a man has a right to kill animals for any purpose, he has the right to perform vivisection, particularly since it is done without pain. Who is more cruel? Doctor Flexner, in devising life saving methods or the women who would shackle him, shut up the Rockefeller institute and thrust all future developments into oblivion?

These same people insist upon spaying animals by the thousands in order that beef and mutton may be tender or have a more pleasant flavor.

Think of the ospreys and egrets in the hats of these same women.

Think of a ship infected with plague and also infested with rats—the carriers of plague—about to enter port.

Do you prefer to kill the rats and so prevent them and the disease from entering the port, causing the dissemination of plague, or save the rats because the slaughter of them would be a painful procedure.

The captain who says spare the rats, is guilty of the criminal act of causing the death of many innocent human beings. So it is with the anti-vivisectionists. They see only the pain inflicted and do not heed the pain prevented. On this score they are in a sense logical when they call Lord Lister, discoverer of antiseptics, a brute, although he, of all men, has been the means of preventing the greatest amount of surgical suffering. They see only the pain which he deliberately inflicted on a few rats and rabbits, they cannot see or they refuse to see the measureless amount of misery he has prevented.

The slight pain animal experimentation causes in the world is trivial when we consider that in the universe thousands and thousands of pains, of fierce incessant struggles between living animals, are going on constantly. Every rock and every tree shelters ferocious combats and is the constant scene of painful death agonies.

Consider that in the entire world only 200,000 animals are sacrificed annually for experimentation; and that two thousand million mammals die every year from natural causes.

By giving an experimental disease to a rabbit, one scarcely changes its lot. Surely the lot of a street dog is improved when it enters an experimental laboratory.

Many anti-vivisectionists amuse themselves by hunting and fishing, while a physiologist is tremendously concerned every time he causes blood to flow or inoculates an animal with disease. I know the thoughts that animate him. The experimenter feels the responsibility of these animal lives.

These men pass their lives in nauseous rooms, amidst poison and virus, receiving no other compensation for long labors than the satisfaction of duty accomplished. It is not in the laboratories of the physiologist that a man grows rich.

Let us consider whether the efforts of experimenters and the sacrifice of animals has paid.

In 1906, Dr. Flexner at Rockefeller Institute, developed a serum for meningitis and sacrificed 25 monkeys and 100 guinea pigs. This one experiment saves thousands of human lives a year.

Careful scientific experimentation has developed a serum for meningitis which directly destroys the growth of germs. As a result the mortality of the disease has been reduced and severe symptoms and crippling complications have been prevented.

In 1878, Koch discovered the tubercle bacilli. Before that time it was thought that tuberculosis was due to a divine anger. Since then tubercular mortality has been reduced 50 per cent. Since Koch, six million people have been saved by progress in hygiene. It has been clearly shown by experimentation that tuberculosis is not inherited.

Animal experimentation has made a rich contribution to children. I fear laymen are insufficiently informed on these important subjects. Hysterical imaginines would discredit this beneficial work. The ones to suffer most from a suppression of animal experimentation are helpless suffering children.

As an illustration, let us consider the ravages of diphtheria in New York City, prior to the use of antitoxin. In 1894 there was a mortality of more than eleven thousand children, while ten years later, after antitoxin had been well introduced, the mortality was but slightly over two thousand. A saving of mortality in one city in one year from one disease was practically nine thousand. It is estimated that since Behring discovered diphtheria antitoxin, one million, three hundred and fifty thousand children in France alone, have been saved by its use. Behring sacrificed one hundred rabbits and twenty-five dogs to make this discovery. In 1895 the mortality rate from diphtheria in nineteen American cities was eighty per one hundred thousand. Ten years later it was seventeen per one hundred thousand. If this rate could be applied throughout the United States, it would mean today an annual saving of sixty thousand children as the result of antitoxin treatment and public health laws.

I wish that the people trying to throttle scientific research, would witness the awful struggle of a child dying from diphtheria croup. Surely they could then realize the importance of these discoveries. Fortunately few physicians are forced to go through such an ordeal at present owing to the beneficent results of treatment resulting directly from animal research.

Hydrophobia has been almost stamped out; and so has benefited dogs as well as human beings.

Smallpox has been practically eliminated in civilized countries by vaccination. During the eighteenth century, sixty million people died of this disease in Europe and multitudes were permanently scarred. The reign of this destruction and death continued until Jenner's discovery in 1796. In Germany, where compulsory vaccination has been enforced, there has not been an epidemic for many years. Adjacent countries not so protected have had numbers of epidemics.

Typhoid fever in armies has killed and maimed more than bullets. In the Spanish-American War, one-fifth of the soldiers in national encampments had typhoid fever. Among one hundred thousand men there were twenty thousand cases and sixteen hundred deaths.

In 90 per cent of volunteer regiments the disease broke out within eight weeks after going to camp.

Contrast this to the recent mobilization in Texas, where but two cases of typhoid developed and both recovered. In 1898 at the Jacksonville camp, with practically the same number of troops, there were two thousand cases and two hundred and forty-eight deaths.

In operative surgery wonderful strides have been made.

Anti-vivisectionists would be content to use the same old horribly dirty methods of surgeons employed in the days before Lister, and thereby offer up thousands of human lives to their Moloch. Lister's discovery of antiseptics has reduced the mortality in simple amputation from 70 per cent to practically nothing. Lord Lister in 1868 sacrificed a few guinea pigs and rats, and we have the above results.

The most useful advances in surgery are not necessarily those which are the most spectacular, nor are these advances based upon accidental or sudden discovery. A great many people have the idea that animal experimentation or other scientific research, consists in striking about hit or miss in the hope that some valuable fact may accidentally show itself. Nothing could be further from the truth. The scientific student starts out with a carefully elaborated theory or belief, to which he has given the utmost thought and his experimental work is conducted along a well prepared plan for the purpose of proving or disproving his preconceived theory.

One of the most interesting developments in surgery of the present generation is that which has as its purpose, the reduction or elimination of so-called "shock," with the purpose of returning the patient to his active vocation in the shortest possible time and of causing the individual the smallest amount of injury through the operation itself.

With all of the benefits which come from properly conducted surgical operations, intelligent surgeons have always recognized that the ordinary administration of ether or chloroform and the ordinary surgical procedure, are accompanied by a certain amount of psychic and physical violence which make their impress upon the mind and body of the patient with certain definite prejudicial results.

This injury is caused in several ways. First, there is the element of fear. Second, the powerful impression carried to the brain through the violence done to the tissues involved in the operation. Third, the depression caused by the deep intoxication of prolonged anæsthesia.

To overcome this element of shock there has been devised a method known as the Nitrous Oxide Oxygen Anosi Association. The process is relatively new, but I am satisfied, from a personal experience of several months, that it is a method which will eventually be adopted by the conservative surgeons of the world.

Briefly, this Anosi theory, as taught by Crile, of Cleveland, assumes that potential energy is stored in the brain, the liver and in suprarenals, and that when this energy is destroyed in sufficient amount, there results a condition known as exhaustion or shock. This discharge of potential energy may be brought about by any insult to the body such as trauma, hemorrhage, starvation, worry, excitement or insomnia, and is produced to an enormous extent in ordinary surgical operations and this discharge is occasioned in surgical operation, although the patient may be thoroughly anaesthetized and unconscious of actual pain. The unconsciousness does not prevent the transference of sensation from the field of operation to the brain, although the patient may be oblivious to the pain which would thereby be occasioned were he awake.

The Anosi Method of handling the patient for surgical operation consists of the following logical steps:

1. The element of fear is eliminated as far as possible, the attitude of the surgeon and his assistants is essentially optimistic and encouraging. The patient is given a preliminary injection of morphine and scopolamine to quiet his anticipation and to reduce the amount of anæsthetic required.

2. On account of its peculiar action upon the brain cells, ether is in itself a shock producing factor, and so in this process we have adopted nitrous oxide, which prevents oxygen reaching the brain. Crile has demonstrated that an operation under ether produces three times the amount of shock that the same operation does when performed under nitrous oxide, and he also shows that the blood pressure under ether falls two and one-half times greater than under nitrous oxide anæthesia.

3. The psychic effect of taking ether is much greater on account of the rather disagreeable odor, and the sense of choking and suffocating occasioned by it, while nitrous oxide is entirely odorless and only a few inhalations will produce unconsciousness.

4. Ether is known to destroy the white cells of the blood, which, as you know, are the natural protectors of the body from bacterial infection. Hence, to a certain extent, ether promotes infection by breaking down the natural resistance to infection.

5. Many surgical operations are known as two step operations, in that they have to be performed at two sittings. Ether anæsthesia is so disagreeable that the patient usually approaches the second operation with the utmost apprehension, while the Anosi Method is so far from being disagreeable that the patient has no fear of the second anæsthesia.

6. To overcome the depressing effect of ether, major operations under local anæsthesia or under spinal anæsthesia were suggested, but it was found that even if these operations were entirely free from pain, the consciousness of the patient that violence was being done to the body, was sufficient to produce considerable shock.

7. Having produced unconsciousness by the method most agreeable to the patient, the Anosi Method includes blocking off the field of operation with a local anæsthetic so that the impulses of the operation are prevented from reaching the brain. In this combination we avoid the psychic stimulation of the brain cells by unconsciousness, and also protect the brain from the shock due to disturbance in the operative field. The method also involves the handling of the operative field with the utmost care on the part of the surgeon.

With an operation conducted with prevention of shock or violence, post-operative nervous exhaustion is almost eliminated and, by blocking off the incision with a solution of quinine and urea hydrochloride, post-operative pain becomes a negligible factor.

Under this method I have had the gratifying experience of having a patient operated upon for appendicitis, removed from the operating table to a wheel chair and permitted to dress and walk about the hospital within six hours after the operation.

When through ether it was found possible to make surgical operations painless and when through asepsis it was found that infection could be avoided, we had a comfortable feeling that we had solved the great problems of surgical procedure and that there were few, if any, great cardinal principles yet to be discovered.

This recent discovery of the element of shock in surgical operations leads us to believe that there is still much to be discovered and that perhaps there yet remains unknown some great factor in surgical development quite as important as anæsthesia or asepsis. Certainly the prevention of shock may be placed on a par with these two great epoch making discoveries.

Symposium on Colloids

OUTLINE OF THE PHYSICAL CHEMISTRY OF COLLOIDS

D. A. MacInnes, University of Illinois.

In the short time at our disposal it will be possible only to discuss some of the outstanding features of the physical chemistry of colloids. Since the first use of the term "colloid" by Thomas Graham in 1861 the subject has advanced so rapidly that no one but a specialist could hope to read all the literature connected with it. There are at present two journals devoted to colloids; the "Kolloide Zeitscrift" and the "Kolloide Beiheft," both edited by Wolfgang Ostwald. Extended treatises on the subject have been written by Ostwald, Zsigmondy, Hatscheck and others, and scientific journals of the most diverse character will be found to contain articles pertaining to colloids at least a few times a year.

In order to get a rough idea of the place colloids occupy in nature let us make the experiment of shaking up some soil in water. There will be a certain portion that will settle out almost as soon as the shaking ceases. Another portion will remain suspended in the water for a short time, but will be separated if the mixture is run through a filter paper. This is usually termed a "coarse suspension." The turbid fluid that has gone through the filter is a colloidal solution. The solid it contains differs from the portion that remained on the filter paper chiefly in the fineness of division of its particles, or in terms more usual in this branch of science, the degree of dispersion of the particles. We may then, following Wo. Ostwald, take the size of the largest particle that will go through a filter paper as the upper limit of the size of colloidal particles. The arbitrary nature of this division will be evident to everyone, but it is in accord with the general usage of chemists. If a precipitate is not stopped by a filter paper a chemist makes expressive remarks concerning colloids. The lower limit of the degree of dispersion of colloids we may also take from Ostwald. This may be given as the size of the smallest particle that will be briefly described later. Now the diameter of the particles that an ordinary filter paper will pass is about 100 $\mu\mu$, or 1-1000 millimeter, and the ultramicroscope can make evident to the eye particles of a diameter of $6\mu\mu$, or six millionths of a millimeter in diameter. We can then agree for the present to consider solutions containing particles of sizes that come within this range as colloidal solutions.

The first investigators in the subject thought that but few substances can be obtained in the colloidal condition. Later, and as the result of an enormous number of researches, it has become evident that practically any solid or liquid substance may, by proper manoeuvering, be obtained in colloidal solution in some solvent. The method of preparing colloidal solutions are quite diverse as a consideration of the following typical examples will show.

(a) A colloidal solution of silver chloride may be prepared by mixing a very dilute solution of silver nitrate with a very dilute solution of common salt. The use of very dilute solutions is a method of producing colloidal solutions of many slightly soluble substances.

(b) An interesting series of colloidal solutions of gold may be prepared by treating gold chloride solutions with reducing agents. These vary from the translucent blue to the transparent orange red solutions. In the latter the gold is in such a fine state of division that the separate particles are scarcely visible in the ultramicroscope.

(c) A colloidal solution of ferric hydroxide may be prepared by simply pouring a few drops of ferric chloride into boiling water.

(d) Bredig's method, which is applicable to a number of metals, consists in causing an electric arc to strike, under water, between electrodes made of the metal of which a colloidal solution is desired. With the use of high frequency alternating currents this method has recently been used in the preparation of colloidal solutions of a number of metals in a great range of degrees of dispersion.

(e) Colloidal tungsten and chromium may be made by treating the finely ground metals alternately with acid and alkali. This is known as the etching method. Colloidal tungsten prepared in this way was used in the manufacture of the early fragile tungsten filaments.

(f) It has also been found possible to prepare colloidal solutions of a number of metals simply by keeping them for a long time in boiling water in the absence of oxygen.

The question now arises; what properties in common have solutions prepared by such different methods and involving such different substances? The size of the particles has already been mentioned, some other properties will be considered in the following paragraphs.

One very interesting and important property of colloidal solutions can be observed only with the ultramicroscope, an instrument which renders the separate particles visible. Under this instrument the particles are observed to be in motion, the more rapid the smaller they are. This phenomenon is known after its discoverer as the Brownian movement. A study of this motion has led in the last few years to a virtual proof of the molecular theory of matter. A review of the work in this field as carried out by Perran and others will not, of course, be possible here. Briefly, however, the basis of it is as follows: In order to account for the observed properties of gases the kinetic theory has postulated that at a given temperature the kinetic energy of all gas molecules is the same. Since the kinetic energy is the product of the mass of the molecule and the square of its velocity, the speed with which a large molecule moves must be smaller than that of a small molecule. On the assumption that the colloidal particle is a very large molecule, it is found that the directly observed velocity of the particles has exactly the value predicted by the kinetic theory of gases.

The optical principle of the ultramicroscope, which has made this and many other investigations on colloids possible, is shown in figure 1. The cell *E*, which holds the colloidal

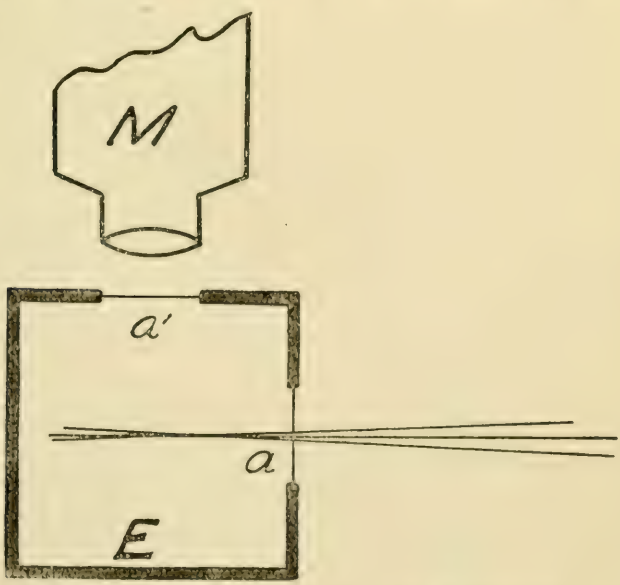

Figure 1. Principle of the Ultra Microscope

solution, has two thin quartz windows, *a* and *a'*. By means of a slit and a series of lenses, rays of light from an arc light enter window *a* in a plane a few thousandths of a millimeter thick. This light impinges on a few of the colloidal particles in the solution and causes them to be centers of light emission. The effect can then be observed by means of an ordinary microscope, *M* against a black background through window *a'*. The same principle is, of course, involved when a ray of sunlight enters a darkened room and makes brilliant spots of light of the motes in the beam.

A property common to colloidal solutions is the slow diffusion of the particles through gelatinous substances and through membranes. Upon this property is based the easiest method of determining whether a solution is colloidal or not. A test of this kind can be made by pouring some gelatin in the bottom of test tubes, and on top of the gelatin solutions of, say, colloidal gold and of potassium dichromate. After an hour or so it will be observed that the dichromate has diffused several millimeters down into the gelatin, whereas the boundary between the gelatin and the colloidal solution is just as sharp as at the beginning of the experiment.

The surface exposed by the colloidal particles to the solvent is, as a simple calculation will show, enormous, so that surface effects that are very slight with ordinary solids may be greatly increased by getting the solids into the colloidal condition. One such surface effect is *adsorbtion.* Willard Gibbs's reasoning led him to the conclusion that any substance the addition of which lowers the surface tension at a solid-liquid or gas-liquid surface is in greater concentration at that surface than in the bulk of the liquid, in other words, the substance is *adsorbed* at the surface. This has been amply verified by experiment. Adsorption phenomena play a large role in the theory of colloids. It can readily be shown that adsorption has a large part in the catalytic effect of colloidal platinum on the decomposition of hydrogen peroxide.

Under most conditions the colloidal particles are found to be charged electrically and will migrate to one pole or the other when an electric current is passed through the solution. The origin of this charge is not entirely clear, and its magnitude and even its sign may be changed by the addition of small quantities of electrolytes. If by some means the electric charge is neutralized the colloidal material is rendered unstable and may be readily coagulated or precipitated.

Of the three general types of colloids only one, the *sol,* has been mentioned in the preceding discussion. A *sol* may be defined as a solid dispersed in a liquid medium. Discussion of the *emulsoids,* or liquids dispersed in liquid media, and of *gels,* or liquids dispersed in solid or semi-solid media, must be omitted both because of their complexity and because of lack of time.

In conclusion, it may be said that the scientific and practical results of the study of colloids have amply repaid for the arduous researches made upon them and we may look for similar if not greater results from the researches to be made in the near future.

SIGNIFICANCE OF COLLOIDAL CHEMISTRY IN PHYSIOLOGY

By William Crocker, University of Chicago.

I. INTRODUCTION

Were we to put today to a large number of physiologists the question, "How much, in your opinion, will the laws of colloidal chemistry illuminate and explain physiological phenomena?" we would get a great diversity of opinion. We would find on one extreme those who believe that the newer branch of chemistry has not led and will not lead to any considerable advance in physiology and, on the other, those who see almost all the problems of biology rooted in colloids and almost all the phenomena peculiar to the living organism finding explanation in the simple laws of heterogeneous systems. With colloidal chemistry in many of its phases a new science and with many of its fundamental laws even now just being established, it is evident that the application of its principles to the complex phenomena of living organisms is a thing to be done with some caution.

The application of the laws of homogeneous solutions to biology has already answered many questions and is still to answer many more. It is likewise evident that it will leave perhaps a greater number, unanswered or explained only on the assumption of vital principles. The laws of heterogeneous solutions are now having their turn at vital problems with excellent prospects of solving many of these along physical chemical lines. To date, however, the significance of colloidal chemistry in biology is more a matter of hope and excellent outlook than of actual accomplishment. This prospect can best be put by a quotation from Höber (1)*: "Biology experiences extraordinarily valuable stimuli as soon as many of its old problems are considered from the standpoint of colloidal chemistry. Consequently every attempt, in any degree possible, to interpret those problems, hitherto not completely understood, into colloidal processes is not only desirable but to be demanded. The materials of the biologist offer sufficient reason for this. For the microscopist must daily consider colloids, when he deals with the effects of fixing, macerating, and staining reagents upon the structures of protoplasm, for visible evidence of these effects rests mainly upon the visibility of solid or precipitated colloids; the medical chemist deals particularly with colloidal albumin bodies: whoever undertakes problems of metabolism finds that most of his riddles are bound up, in a large measure, with colloidal ferments and any one who undertakes in these days the analysis of any fundamental physiological phenomenon will observe that it is not in vain that protoplasm consists largely of colloids, that all of the more delicate and grosser membranes, which serve for the isolation and regulation of biochemical processes, are colloidal membranes. It may be emphasized that a study of immunity reactions presupposes a knowledge of colloidal properties, since toxins, antitoxins, alexins, agglutinins and lysins are colloids."

II COLLOIDAL NATURE OF LIVING CELLS

The structure of the protoplasm, its organs and the parts produced by it, has been the phase of biology of perhaps most general interest to which the knowledge of colloids have contributed. The students of colloids are coming more and more to view the protoplasm and its individual organs as typical hydrosols or as hydrogels, and it must be acknowledged that they are accumulating much evidence for this conception. From this viewpoint the following are the more prominent of the questions worked upon. In how far are the structures of the cell and its accessory parts hydrosols and how far hydrogels? What are the structure of gels and sols in general, including the protoplasmic gels and sols? Are colloidal structures complex enough to satisfy the demands of protoplasmic processes.

In answering the first question Czapeck (2) states that cell membranes, gums and starch grains are gels, as well as a number of protoplasmic organs, such as nuclei and many chromatophores.

*Figures in parenthesis refer to the bibliography at the end of this paper.

Kite (3), in work marked by excellency and delicacy of technique, has done much toward answering this question. By using an adaption of the Barber pipette as a dissecting knife he has cut away various portions of a considerable number of different sorts of plant and animal cells, determining the consistency, elasticity, and other physical characters of various cell organs. His work shows that protoplasmic parts are much more frequently gels than is generally supposed, and that the same organs in cells of different organisms may have very different characters. The nucleus of Asterias egg is a free flowing sol covered with a very tough consistent membrane and bearing a nucleolus of rigid cohesive granular gel. The nucleus of Spirogyra is a gel of rather slight viscosity bearing a network of granules and strands of greater consistency. The nucleus of epithelial cells of Necturus is a gel of greater viscosity bearing areas of rigid granules, giving an appearance of threads. Chloroplasts and many other organs show great range of viscosity, varying from sols to consistent gels. Kite finds that in general the animal cells are more viscous and consistent than the corresponding organs of plant cells.

There is no reason for believing that there is a transformation from gels to sols and vice versa, with a change of conditions in protoplasm as in vitro. The conditions important in producing such transformations are temperature changes, changes in hydrogen, hydroxyl, and salts ion content.

As to the second question—structure of gels—there are two rather distinct pictures. One was developed by Bütschli and confirmed and extended by Van Bemmelen (2, p. 10). They consider gels to be solid colloids with solid dispersal medium and fluid disperse phase. This is Bütschli's well-known foam structure. The frame work of the gel consists of the gel forming materials with little water imbibed, surrounding numerous spherical cavities filled with a water rich hydrosol of the gel forming material. This foam structure can be seen with the microscope in many hydrogels, especially after displacing the water with alcohol or after slight drying. The mesh size of the foam structure varies considerably with the sort of gel studied and in some is apparently ultramicroscopical. The people holding this view of gel structure extend it to hydrosols as well, so even the more fluid portions of the protoplasm are conceived as foam-like.

This picture of hydrosols is very different from the more strictly colloidal conception (1: pp. 312-316). According to the latter view hydrosols consist of discrete particles of the colloid dispersed in water. In the hydrophyllous group the particles are more or less swollen by the absorption of water. The advocates of this view extend this conception of hydrosols to hydrogels. In the gel the imbibed or hydrated particles crowd upon each other, giving high viscosity.

It is estimated that in a 6 per cent casein solution the swollen submicrons or amicrons occupy about 60 per cent and in a 9.4 per cent solution about 80 per cent of the space of the total solution. There are several reasons offered for postulating this structure. Both a gelatin solution too dilute to gel and one sufficiently concentrated to gel show numerous submicrons as they cool, but no difference between the two can be detected by the ultramicroscope. Each can be flocculated by salt additions with the same relative effectiveness of the ions. There are points of similarity between the phenomena resulting from mixing with water certain hydrating crystalloids like sulfuric acid and glycerin and those of swelling gels. High dispersion of these gels along with their hydration gives them many of the characters of true solutions. The degree of dispersion of gelatin is not known, but it is certain that haemoglobin forms a molecular solution.

It is not believed that the foam structure of Bütschli and VanBemmelen is an ever present structure of gels. It is considered that the foam structure is one of several deformations produced in gels by a variety of reagents or by pressure and temperature changes. A number of workers have studied separations of this type produced in gels and sols. We may draw a good illustration from Hardy's work (4). He found that when gelatin was treated with concentrated sublimate or other killing or fixing agents a variety of structures appeared depending upon the concentration of gelatin and the reagent used. From dilute solutions treated with sublimate the gelatin falls out as individual granules, from medium concentrations as a network of granules and in concentrations of 5-7 per cent or above a foam structure appears. The more concentrated the gel the thicker the walls of the foam and the smaller the enclosed cavities. In 10 per cent gelatin the cavities were 7μ in diameter and in 50 per cent gelatin 2.5 μ in diameter. These reactions were reversible or irreversible, depending on the reagent used. Protoplasm shows very similar behavior in all respects with perhaps a greater sensitive to reagents, both as to deformation and irreversibility, and these reactions may in large part explain the various theories of protoplasmic structures. It seems established now that these reversible flocculations occur in normal living protoplasm. The irreversible ones, if extensive, lead to death.

In protoplasm the multiple vacuolate condition may have another origin as is shown by Bensley (5), in his late work on the canalicular systems of plant and animal cells. He concludes with the sentence, "I regard, therefore, the canalicular system as the true condition intra vitum of the vacuolar apparatus in these cells of the root tip, and believe that the multiple vacuole condition is of secondary origin due in most cases to injury of the cell." Here while the origin of the multiple vacuolate condition is different from that found by Hardy in gelatin gells, it is nevertheless a deformation of the prevailing structures.

In answer to the third question above, Are colloidal structures complex enough to satisfy the demands of protoplasmic processes? it should be stated that many reactions are occurring in a cell coincidently—reactions of the most diverse character and of antagonistic types. On this basis Hofmeister (6) believed there must be a special structure offering compartments separated by membranes of special permeability characters to isolate and regulate these reactions. This he thought doubly necessary for cells with few special organs. The foam structure of protoplasm cares amply for this chemical necessity, especially if the walls of the foam are endowed with permeable qualities varying with conditions and with location in the cell.

Some of the students holding to the more strictly colloidal conception offer a number of arguments against this view. Protoplasmic movements argue against such a structure. The ultramicroscope generally fails to reveal foam structure in gels and sols in vitro as well as in the protoplasm. Such structures are apparently not ever present, but are formed as a result of certain accompanying conditions.

As our intra vitum staining methods improve and as new methods of the direct study of the living protoplasm are developed, such as the dissecting method of Kite, we are finding more and more bodies of micronic size in the cell. These are included under a variety of names such as mitachondria, chondriasomes, etc. If we remember that colloidal particles of this nature generally surround themselves with special membranes, which give them peculiar permeability characters, it is easy to see that here again is the possibility of the isolation and regulation of chemical reactions. Aside from these the ordinary plant cell has plastids, vacuoles, or canalicular systems and nuclei.

If in the frame-work and cell wall systems of plants in general such a simple structure is primary, there must also exist a secondary and grosser structure which determines the anisotrophy as manifested in unequal swelling along the several axes due to water absorption. Wood, for instance, swells most tangentially, less radially and least longitudinally, while a great variety of unequal swelling appears in wall structures showing hygroscopic movements. In some of these cases only a single wall is involved, showing anisotrophy to exist in rather minute structures whether primary or secondary. The multivacuolate conception of gel structure lends itself more readily to the explanation of this anisotrophy, for with water gain and loss the vacuoles may show greater dilation and contraction in certain axes than in others (7: pp. 745-552).

The thing of greatest biological interest in the study of hydrosols and hydrogels, including the protoplasm, is not any specific structure found, but the capacity for the assumption of one or another structure with variation in condition. The reaction is now reversible and now irreversible. While such modifications are brought about with relative ease in gels and sols in vitro, it seems that living protoplasm and its constituents are even more labile. This is illustrated by Lepeschkin's (8a) work showing that slight pressure will cause a reversible flocculation of cell proteins of Spirogyra and greater pressure, a permanent coagulation and death. Pressure alone does not coagulate protein in vitro. According to Lepeschkin some of the proteins of plant cells essentials to life would coagulate in a few hours, or at most a few days, at 20° C, if there were not dispersion processes in the living cell counteracting the coagulation processes (8b). The proteins in vitro at the same temperature require thousands of years for coagulations.

The way investigators of colloids are attempting to change our conception of the structure of living matter is well illustrated by the work on the ordinary green chloroplast. Earlier work indicates a definite structure of this organ, but different investigators give very different pictures. One speaks of the cytoplasmic stroma as a sponge-like framework with definitely organized granules of pigment filling the cavities, another of the pigment itself in the framework with the protein filling the cavities, and a third of the surface distribution of the pigment. Liebaldt (9) has lately studied the structure of this organ from the standpoint of colloids and finds that the normal living chloroplast is generally homogeneous when viewed either with the microscope or the ultramicroscope. Allowing for oil droplets and starch grains she speaks of the lipoid pigment phase as distributed through the hydroid protein phase to amicronic dimensions. This distribution is easily deformed by various reagents giving all types of structure formerly claimed for the organ. Excessive water absorption caused by opening the cells and bringing the chloroplasts directly into contact with water or even by long soaking of the entire leaf, produces a variety of deformations. As shown by staining reactions, water never produces a complete separation of the two phases. Such altered structures appear frequently in nature and they probably result from peculiar water relations of the plastid. Surface tension active substances as well as other fixing and killing agents in sufficient concentration cause a complete separation of the two phases. This emphasizes the great danger of concluding as to the structure of a living cell from fixed and stained material. (See also citation 4).

Other evidence is offered for the colloidal state of chlorophyll in the living plastid. It has been known for a long time that chlorophyll in an alcohol solution is readily decomposed by sunlight. This has called for an explanation of the apparent or real light stability of chlorophyll in the illuminated leaf. Wiesner believed that protective action of fatty bodies and continual synthesis account for the maintained amount, while Reinke suggested that chlorophyll forms a light stable compound with proteins of the plastid. Iwanowski (10) accepts neither of these views, but thinks the light stability of chlorophyll is explained on the basis of the colloidal condition in the plastid. He found chlorophyll extract in 49 per cent alcohol far more light resistant than that in 95 per cent alcohol. In the former case it is in colloidal solution, in the latter molecular. He also shows that as the colloidal concentration of the solution increases and the degree of dispersion correspondingly decreasess light stability rises. Finally in the concentration and degree of dispersion probably existing in the chloroplast, it is light stable. While the Iwanowski conception has evidence in its favor there is also no important evidence against the Reinke view. Iwanowski also finds evidence for carotin and xanthophyll of the plastid protecting the chlorophyll against light destruction. Herlitzka (11), using carefully purified chlorophyll, finds that it shows little if any fluorescence in collodial solution, while this property is very evident in a molecular solution. The lack of marked fluorescence in the plastid is probably due to the colloidal state of the pigment as well as to the turbidity of the plastid, formerly offered as the explanation.

III SOME GENERAL CHARACTERISTICS OF CELL COLLOIDS

The protoplasm is optically isotropic, while some of its products (starch grains, cell walls and crystalloids) are optically anisotropic. It is believed that the double refraction of starch grains and cell walls can be explained on the basis either of impregnating materials, as in the cuticle, or tension within the gels of these structures; and that the property furnishes no argument in favor of their crystalline structure as against their hydrogel nature (1). With time, however, it seems that the line between crystalline and amorphous bodies becomes distance. (12: pp. 66-75).

The colloidal constituents of the living cell bear negative charges. As a result living cells themselves are electronegative. This has been shown for lecithin, chlesterin, proteins, chlorophyll, blood corpuscles, bacteria and spermatozoa.

When Graham divided matter into two classes—crystalloids and colloids—he thought these two divisions were quite distinct. One of the principal characteristics for distinguishing the two classes was their diffusibility through gelatin or other colloidal membranes. We know that the two classes of substances are not so distinct but that colloidal solutions range in their degree of dispersion from suspensions with microscopically visible particles, on one extremity to molecular dispersions on the other. The hydrophyllous colloids of the living body, which are of greater interest to the biologist, are very highly dispersed, approaching in general the molecular state. It is now well known, for example, that hæmoglobin forms a molecular solution. Along with this very high dispersion they have the character of diffusing with ease through a variety of colloidal membranes. Egg albumin and hæmoglobin diffuse through gelatin plates. Pepsin diffuses into cubes of coagulated albumin. The immunity bodies diffuse through a great variety of colloidal membranes (gelatin and agar plates, dead intestine walls and others). This raises the question of how they are retained within the living cell. This question becomes especially urgent if Ruhland (13) is correct in his conclusion that for colloidal solutions the protoplasm acts as an ultra filter. We shall later see his explanation for the retention of certain enzymes by the cell and their localization within it.

IV WATER RELATIONS OF CELL COLLOIDS

There are certain characters of hydrophyllous gels and sols that are assuming great importance physiologically. One of the more significant is the water absorbing power of these as affected by various reagents. Water absorption by gels and sols is often spoken of as hydration, although this is strongly condemned by Van Bemmelen as incorrectly emphasizing chemical union of the water with the colloid. A great part of the knowledge in this field we owe to the efforts of Martin Fischer (14). The more significant facts known for gelatin and fibrin are: acids, alkalies and urea greatly increase water absorption; some anions of alkali metals increase water absorption (Rhodonate Cl, Br, NO_3.) and others decrease it (SO_4, PO_4, Tartr., Citr.) (2: p. 43); salts in general inhibit the hydrating effects of acids and bases and the total effect of the salt is due to the joint action of the two ions; non-electrolytes show influence on the hydration effects of acids and alkalies; sugar and other non-electrolytes reduce greatly the hydration effects of urea, while electrolytes show little influence. Fischer finds these reagents act on the hydrophyllous colloids of the body, especially the proteins of the cells and fluids, exactly as they do upon gelatin and fibrin. He concludes from his work that dropsy in the animal body is produced by the presence of agents that favor water absorption by colloids of the body. Amongst these, acids and urea are the more important. Intravenous injections of salts, alkalies and dextrose are effective in reducing edema by dehydrating tissues and fluids of the body on the same basis as they act on gelatin and fibrin. In fact he finds the cause and therapeutics of dropsy tied up with water absorption by body colloids. From this extensive work Fischer concludes that absorption by colloids and modification of it by various factors play the main part in water relations and secretions in the animal body; while osmotic pressure is of very minor importance. This is a reversal of the general view and brings colloids into prominence in contrast to crystalloids, which, although they act by the help of colloidal semipermeable membranes, are the main source of osmotic pressure.

Whatever may be true in the animal, one who knows the very extensive literature on the water relations of plants cannot give osmotic pressure such a minor role there. It is probably just as true that the significance of water absorption by colloids has been greatly underrated in plant physiology. This is due to the over shadowing prominence given to osmotic pressure and the resulting turgor pressure. We generally think of the plant cell with its large vacuole and cell wall as pre-eminently an osmotic machine. One is surprised when Borowikow (15) announces that a root placed in .01 M. HCl elongates twice as fast as in distilled water. It behaves much like a piece of gelatin, although it ought to exhibit osmotic activity at its optimum. The elongation is of course temporary for the high concentration of acid soon proves fatal. Lower concentrations of acid increase the rate of elongation, but less considerably and for a longer period. There seems to be evidence for the view that rate of growth in plants is regulated to a considerable degree by organic acids formed (15, 16, 18). Whether this is due in the main to the hydration effect of the H+, or whether the acids also favor the formation and activation of enzymes, or perhaps other processes are effective, is not established.

Acids and bases increase the rate of water absorption by seeds and they are good forcing agents for many seeds (16, 17, 18). This forcing effect in some cases is due to increased water absorption by the seed coat. In other seeds the reagents have this and other effects upon the embryos. I shall be surprised if the often mentioned forcing powers of neutral salts for seeds is not due in many cases to its effect upon water absorption by gels of the seed coats and the endosperm. Assuming that these gels are electro-negative one would expect such salts as lithium, sodium and potassium chlorate, nitrate or chloride to increase water absorption while salts involving calcium or sulphate might have the opposite effect.

As yet, however, we know very little about the role of these reagents in water absorption by carbohydrate gels, which are so prominent in seed coats. There are peculiar cases (19) recorded, such as the power of potassium salts to increase the water absorption and cause the final dissolution of the cell walls in the growing zone of roots.

Calcium salts alone or in combination with other salts on the other hand, maintain the proper consistency of the walls and integrity of the roots. In fact Cranner finds that in general potassium salts greatly favor the absorption of water by cell walls and inhibit the evaporation of water from them; while calcium salts have the opposite effect. The effect of these salts upon water absorption and retention by the cell wall is similar to their effect upon transpiration which indicates that they modify the latter process, at least in part and perhaps in the main, quite independent of the protoplasm.

Calcium ions tend to maintain the proper consistency of the intracellular cements of animal cells, while potassium ions lead to their dissolution (1).

In this connection we should mention certain effects of calcium and other bivalent and even trivalent ions upon the protoplasm. They reduce the permeability of the protoplasm (plasmahaut?) to salts of the alkali metals and many other substances (20, 21), thus probably reducing the toxicity of these substances to the organism. This effect has been described under the term antagonism. Recognizing Cranner's contribution, wall as well as the plasmahaut effects may be involved in antagonism[1]. It is also not proved that antagonism results alone from permeability change. It may include adsorption phenomena (2: p. 60; 21) or something quite different, such as induced or stimulus effects rather than direct physical changes.

We might summarize what we have said on the relation of various substances (ions and molecules, especially of salts, acids, bases and anesthetics) upon colloids of the living cell. In certain concentrations and mixtures they maintain the consistence and other physical characters of cell colloids necessary for the proper functioning of the organism. Höber and others emphasize in this connection the colloids of the plasmahaut and believe that the effect of these substances upon the irritability, permeability (35), *etc., of the organism can largely be explained through their effects upon this organ* (1:pp.—). *Cranner* (19) *would emphasize in addition their importance in maintaining the proper consistency of the cell walls in plants; while Martin Fischer sees no less significance in their effects upon all colloids of the organism, including sols as well as gels.*

Besides the general nutrient function of salts in plants, such as the use of nitrates, phosphates, sulphates and magnesium for the synthesis of proteins, nucleoproteins, lecithin, chlorophyll, etc., all salts or rather all ions of salts have effect on the physical characters of the colloids of the organism. The necessity of calcium for most plants can best be explained today by its function in maintaining the proper consistency of the colloids of the organism wall and protoplasm. We have much yet to learn concerning calcium in this regard and even more concerning potassium, magnesium and other ions[2].

There is evidence that some very important morphogenic or development changes are brought about by changes in the amount of water held by cell colloids at the time particular processes are occurring in the organism. Certain work indicates

1. Indeed it is not established that the plasmahaut alone determines the entrance of materials into the cell. Other layers of the protoplasm may be involved and in plants the permeability characters of walls and change of these with conditions should not be neglected. This is especially emphasized by recent study of many walls in seed coats showing peculiar osmotic characters in part at least resembling those of the plasmahaut.

2. This is not denying still other functions of salts in plants.

that sex may in some cases be determined by the water content of the egg colloids at the time of fertilization. Eggs of frogs fertilized when laid give about half and half male and female. If they soak in the watery fluids of the oviduct of the female for some hours or days before fertilization they give predominently (sometimes 100 per cent) males. If toad eggs are fertilized as soon as laid they produce about half males and half females, but if dessicated before fertilization females dominated, in some experiments 9 to 1. In hybrids between certain pigeons Riddle finds high water content of the yolk generally correlated with maleness and low water content with femaleness (22).

On the plant side also there are results that may be interpreted as meaning that water content of cell colloids of various primordia have a prominent part in determining the course of development of those primordia. According to MacCallum (23) the markedly different type of leaves in Proserpinaca palustris developing in water and air is due to differences in water contents and Klebs (7: p. 488) finds that in flowering plants high water and salt supply (especially nitrates) leads to vegetative growth, while low water and salt (especially nitrates) along with high carbohydrates induced reproduction. The nitrates here belonging as they do to the least hydrated end of the lyotropic anion series may act similarly to greatly increased water supply by inducing greater hydration of the cell colloids[1].

From these illustrations the question naturally arises: Why does the degree of hydration, or water imbibition, by the protoplasm play such an important role in the course of development of the primordia? The question is not capable of answer at present. It should be pointed out, however, that many other physical characters (viscosity, degree of dispersion, etc.) of the colloidal mass vary correlatively with water supply[2].

In the mammal nervous control and internal secretions, acting perhaps through correlations, are two very important morphogenic determiners. If the degree of hydration of colloids turns out to be as significant as the illustrations above indicate we have here a point of great interest.

Schroeder (2: p. 42) has pointed out a character of colloids that has much of interest to the plant physiologists. He finds that a gelatin gel is in equilibrium with a saturated atmosphere when it contains about 40 per cent of its dry weight in water

1. This interpretation is quite different from that given by Klebs.

2. Here some will contend that turgor pressure rather than hydration of colloids is the determining condition.

and with liquid water when it contains about 1100 per cent. If gelatin fully imbibed in a saturated atmosphere, is placed in water a rapid absorption occurs and the liquid water equilibrium is finally approximately reached. The reverse process takes place when a gel fully imbibed in liquid water is placed in a saturated atmosphere. Filter paper absorbs about equal amounts from saturated atmosphere and water. This character of gelatin and other gels is not certainly explained physically, but that does not concern the biologist so much as the question of whether the living body behaves similarly. Martin (24 and unpublished work) has found an exact counterpart of this behavior of gels in the pollen of alfalfa. The pollen has a very narrow range of water supply necessary for its germination. This is the main factor in the uncertainty of seed production—a matter of considerable economic significance in the United States. In distilled water the grains swell rapidly and burst. In a saturated atmosphere they germinate rather abundantly; but will not germinate in an atmosphere appreciably below the point of saturation. A number of experiments indicate that the final water equilibrium is an important factor here, although the rate of water absorption is likely of some significance. Shull (unpublished work) has found for several sorts of seeds that they contain much more water when in equilibrium with distilled water than when in equilibrium with saturated atmosphere.

If the entire plant acts like a piece of gelatin it should transpire to a saturated atmosphere when its lower end is in water. Dixon (25) claims that this occurs. This character of gels may be acting along with raised temperature due to absorption of radiant energy in maintaining transportation in plants of tropical rainy regions. It is a common thing in plant physiology to grow what are naturally soil or water roots in a saturated atmosphere and assume that they are in a normal condition. Aside from the rate of water absorption we have this character of gels raising a question as to the amount capable of being absorbed. Every worker in plant physiology has observed peculiar characters in roots grown in saturated atmosphere, such as reduced rate of elongation and profusion of root hairs. This gel character of plants may also play a part in guttation.

V DIFFUSION IN A COLLOIDAL MEDIUM

Peculiar diffusion and precipitation phenomena occur in colloidal substrata. Küster (26) attempts to relate these causally with the most diverse features of plant anatomy. His point of departure is the Liesegang ring system. This concentric ring system is produced in a few hours after placing a droplet of 80 per cent $AgNO_3$ on a 5-10 per cent gelatin plate bearing one per cent $K_2Cr_2O_7$. The rings consist of Ag_2CrO_4 and become more definite and more distinct from each other as the distance from the drop increases. The explanation of this phenomenon is still in question, although it may be due to the colloidal substratum making possible great supersaturation before the labile equilibrium is reached. The bands formed in gelatin in capillary tubes show definite rhythm and polarity. Aside from the $Ag_2\ CrO_4$ bands there are others caused by impurities in the gelatin which Küster terms small rhythms in contract to the great rhythms of $Ag_2\ CrO_4$. Contact with the dish in contrast to free gelatin, tensions, pressures and many other conditions, produce a great variety of precipitation figures. In fact patterns can be produced that resemble closely all the various structures appearing in mottled leaves, in the arrangement of vascular elements of plants and the markings of tracheae. Küster emphasizes the fact that the pattern differentiation of $Ag_2\ CrO_4$ precipitate shown in the gelatin plate is a self differentiation occurring under constant environmental conditions. This is taken to show that similar periodic or rhythmic structural changes in the cells may be independent of rhythm in the environment, a matter of self-differentiation. The work also indicates the possibility of separating such differentiation from vitalistic peculiarities. The fact that a simple diffusion process in gelatin gives complex polarized precipitation patterns leads the author to conclude that perhaps a complex pattern in the organism may likewise be referred to a simple diffusion process in a colloidal matrix rather than explained by appeal to complex regulative action of living protoplasm.

Rhythm in plant activity is held by many to be generally related to environmental rhythm. Others feel that rhythm is a necessity of the very nature of protoplasmic activity; activity must be followed by rest. An examination of the facts that Küster offers shows the possibility of rhythms in the organism independent of the inscrutable features of protoplasm. In short, internally determined rhythms may be matters of relatively simple physical and chemical laws. Bringing this third possibility of structural rhythm and polarity into prominence is the great contribution here. The work really has not explained in terms of process of formation a single plant or animal structure.

If the explanation of Ostwald mentioned above is correct, it means that a colloidal medium of the type of a gel favors the maintenance of supersaturation, or of a metastable equilibrium. Likewise it seems to favor supercooling as does any capillary system. This last feature of colloids is claimed to be of importance in protecting the organism against death from low temperatures (1: pp. 50, 58, 27). The full discussion of this point, pro and con, would lead us, however, too far away from the main topic under consideration. A colloidal medium then seems to favor these two "Uberschreitungserscheinungen," supersaturation and supercooling, and perhaps through these explain certain behavior of organisms.

VI ENZYMES AS COLLOIDS

Enzymes which play the main role in the metabolism of living organism, have many characters indicating their colloidal nature. They are readily adsorbed by fine suspensions or other colloids. This adsorption is probably due in part to their surface tension activity, and in part to their electrical characters. In the first instance they show themselves closely related to the hydrophyllous colloids. In the second they manifest weak suspensoid characters (2: pp. 95-127).

Even the strongest argument against their colloidal nature —the fact that they never have been prepared in a pure state and that we therefore do not know their true nature—is an argument favoring it also, for it is an outcome of high adsorption capacity.

Grüss was able to separate the various enzymes of a plant organ by placing a drop of its juice on a stretched filter paper. As the drop spreads the enzymes arrange themselves in rings about its center in order of ease of adsorption by the paper. That the electrical charge of the enzyme particle is sometimes a factor in its adsorption is shown by the following reactions: kaolin, a negative suspension, will not adsorb invertase, a negative colloid, but *tonert*, a positive suspension, adsorbs invertase readily. Kaolin will adsorb malt diastase only if the diastase is acid in reaction, or is a positive colloid. In a neutral medium malt diastase, like trypsin, pepsin, and ptyalin, is nearly amphoteric, so the adsorption of all is more a matter of surface tension. Filtering of enzymes through charcoal or repeatedly through filter paper lowers their activity due to adsorption by the filter. The colloidal nature of enzymes has been called into play as a means of explaining their retention within the living cell. Hoffmeister believed their colloidal character prevented them from diffusing through membranes generally and especially through protoplasmic membranes. On this basis he conceived that they were not only held within the cell, but also localized within the separate compartments of the multivacuolate protoplasm, as he pictured it. It has been shown, however, that enzymes are very highly dispersed colloids and that they diffuse readily through 10 per cent gelatin and Ruhland (13) believes through cell walls and protoplasm generally. This author thinks retention within the cell is due either to adsorption or more likely to actual chemical union with the protoplasm. He believes that this also accounts for the localization of enzymes within the cell.

In many of their activities enzymes behave like colloids. The question has often been raised whether their main function is a typical colloidal reaction or more of the nature of reactions in molecular solutions. The evidence generally is in favor of the second. In the first case diffusion should play the main role and the speed coefficient for 10°C rise in temperature should not exceed 1.25. For lipase, invertase, catalase, and tryosonase the coefficient is about 1.5, but for most enzymes it is from 2 to 3. Where the coefficient is as low as 1.5 diffusion between the two phases of the system (aided by increased Brownian movement of the enzymes and reduced viscosity of the medium) may be the main rate determining process; but where the coefficient lies between 2 and 3 the rate is probably determined by a reaction typical of homogeneous systems. The action of enzymes is, however, very complex, involving adsorption by the substratum and often by products of their action, and many other disturbing factors. As a consequence we are far from a quantitative statement of the kinetics of enzymes.

VII IMMUNITY BODIES AS COLLOIDS

In general when the physiological significance of colloids is discussed the characters and behavior of immunity bodies are used as illustrations. These show much in common with enzymes and many of the questions concerning the colloidal nature of the one has been asked and answered similarly for the other. Space does not permit the discussion of the colloidal characters of this group of substances and besides an excellent statement can be found in many texts (1, 2, 28).

VIII SOME COLLOIDAL PHENOMENA OF SOILS

There is a large number of reactions in the soil that are colloidal in nature and of great interest to the plant physiologist. The soil is the environment of approximately one-half of each land plant and, so far as many processes are concerned, the more interesting, if the less well understood, half. Flocculation, a process by which clay soils are rendered more penetrable and given a better oxygen supply, is a typical reaction between suspensoids and suspensions and electrolytes. It is well illustrated in delta formations at the mouths of rivers where the silt and clay constituents of the fresh water are brought into contact with the salts of the sea water and flocculated. The effect here is mainly due to the cations of the salt acting on the negatively charged soil particles. Deflocculation, brought about by the addition of excess of flocculating salts, is a well known reaction of suspensions and suspensoids included under the term peptisation (1: p. 293-295).

The dissolution and removal from the soil of lime carbonate, its natural sweetener or neutralizer, and the final accumulation of acid in it, is in part at least due to flocculation. The positive ions of the inorganic salts are absorbed by the organic and inorganic negative soil particles and the latter are flocculated, leaving free in the soil the strong inorganic acids corresponding to the negative ions of the salt. The soil particles thus flocculated may be of microscopical size, or suspensions, or of ultramicroscopical size—true colloids; but the principle of the reaction is the same in either case. Flocculation, in part at least, explains the mysterious humic acids of the soils that have been so much discussed without certain identification and so far as it does account for the acidity shows that the acids are largely not organic but inorganic.

Daikuhara (29) has lately brought evidence to show that the injurious effects of adding fertilizer salts to many soils of Japan and Korea, poor in lime, are due to the fertilizer salts freeing complex acid salts of aluminium and iron from adsorbed condition on the colloids of the soil. If lime accompany the fertilizers very beneficial effects results from them. He implies that the same may be true in America where acid soils are so prevalent.

Litmus paper as a qualitative test for soil acidity has its short-comings in the differential adsorption of the two ions of the organic salts of the litmus by the suspensions and suspensoids of the soil on one hand, and by the collcids of the paper on the other—typical adsorption processes of suspensoids. The common quantitative tests for soil acidity are rendered unsatisfactory on similar grounds (30).

Of course, no one will claim that the total loss of lime carbonate from the soil (about 800 lbs. per acre per year) along with the final assumption of the acid character by the soil is due solely to the acids set free by the flocculation of organic and inorganic suspensoids of the soil. There are a great number of acid forming processes going on in the soil; carbon dioxide production of the respiration and fermentation of soil organisms and nitric acid production by the nitrifying processes (oxidation of ammonia salts to nitric acid by nitrosomonas and nitrobacter) may be mentioned as two important ones.

As one passes from the coarse sands to the finer clay he finds a continual rise in the specific surface presented by the soil—that is, a continual rise in the total surface of the soil particles per unit volume. The high specific surface of the finer soils is due in part to particles of micronic or microscopic size, but in large part to the ultramicroscopic or submicronic particles—soil colloids, inorganic and organic. The great specific surface developed in fine soils, especially those with considerable colloidal constituents brings about much adsorption or concentration of dissolved and suspended substances on the surface of the soil particles. This surface accumulation is due in part to electrical effects typical of suspensoids and in part to the surface tension active substances in accordance with the Gibbs-Thompson law. Whatever the cause of these surface concentrations the result is that many new reactions are set up between the concentrated materials themselves and between them and the soil particles. We often speak of sandy soils being poor in plant nutrients, while clays are rich. This is largely due to the surface phenomena and the reactions resulting from them.

In fact any good soil shows many of the characters of a colloidal medium, or is essentially a colloid, as is well expressed by a quotation from Russell's Monograph (31) on Soil Conditions and Plant Growth, "It is a mistake to suppose—and this point cannot be too strongly emphasized—that the medium on which the soil organisms live, and which is in contact with the plant roots, is the inert mineral matter that forms the bulk of the soil. Instead, the medium is the colloidal complex of organic and inorganic compounds usually more or less saturated with water, that envelops the mineral particles. It is therefore analogous to the plates of nutrient jelly used by bacteriologists, while the mineral particles serve mainly to support the medium and control the supply of air and water and, to some extent, the temperature."

IX TOPICS IN COLLOIDAL CHEMISTRY AND THEIR BEARING UPON PHYSIOLOGY

Almost any topic commonly discussed under hydrophyllous colloids can also be discussed in important biological relations. Let us select three of a considerable number of such topics for brief consideration: hysteresis, protective action of hydrophyllous colloids, and the anion series of alkali salts.

Hysteresis, or spontaneous ageing changes, so common in colloids has many points of physiological interest. These are well illustrated in vitro by the slow or rapid flocculation of any colloidal solution; by the reaction between immune bodies becoming irreversible with time and by changes in the vapor tension of gels, continuing for weeks or months after their formation. No doubt many changes in the living or non-living parts of the organism fall under this head.

Seeds in dry storage lose their power to germinate gradually—some even after a year and others only after a century and a half. This is likely due to slow coagulation of embryo proteins (32). Seeds of Amaranthus retroflexus will not germinate when harvested, but will do so after a month or two of storage under uniform conditions. This is a result of spontaneous ageing changes in the gels of the seed coats. Such ageing changes have also been observed in spores. Heating the oat coleoptile to 39°C for one hour lowers the rate of photo-perception at 20°C fourfold. After four hours at 20°C the old speed is regained. This recovery has been interpreted as a matter of hysteresis in cell colloids rather than elimination of poisons formed at the higher temperatures, although the latter interpretation is possible The main virtue of classifying some of the spontaneous changes in the organism under the term hysteresis is not that it furnishes in itself an explanation of them. It takes these problems out of their connection with vital qualities and places them on the basis of a colloidal substratum capable of physical and chemical study.

Protective colloids are colloids of the hydrophyllous type which have the character of forming a film about the particles of suspensions or suspensoids and preventing their flocculation. Blood serum often bears uric acid far above the saturation point. Albumins of the serum of the blood acting as protective colloids keep the droplets of uric acid in suspension. The droplets vary in size from amicrons to microns, depending upon the degree of supersaturation. The high content of calcium phosphate in milk is probably explained on a similar basis. Gall stones and bladder stones are in part due to short-age of protective colloids for holding certain insoluble substances in suspension.

Hofmeister showed that certain anions of alkali salts decrease the amounts of water absorbed by gelatin gel, while others increase it. The sulfate, tartrate, citrate, and acetate anions cause shrinkage, while bromides, nitrates and rhodonates cause swelling. Starting with this determination a great amount of later work has led to a rather definite arrangement of the anions of alkali salts in relation to this as well as other characters of colloids and to a number of physical and chemical processes in homogeneous solutions (1: pp. 309-326). The following are interesting colloidal applications of this series. In salting out hydrophyllous colloids, the sulfate-tartrate end is most effective, while certain anions of the opposite end of the series cause dissolution. The same order holds in the productions of gels from sols. The cations show less range in effectiveness, but they too can be arranged especially in regard to precipitation of colloids, in definite order reversed, however, with a reversal in the charge. We generally consider tropic movements in plants, so far as their underlying causes and processes are concerned, as amongst the most complex of plant phenomena. Porodko (33) shows in a recent publication that the effectiveness of the anions of salts of alkali metals in producing positive chemotropism follows almost exactly this series: Tartrate > citrate > sulfate > acetate > chlorate > chloride > nitrate > iodide > cyanide. The effectiveness of their cations for positive chemotropism also approximated their effectiveness for the precipitation of colloids in an acid medium, thus: rubidum > caesium > potassium > lithium > sodium. Bromide does not cause positive chemotropism. These and a number of other facts discovered by Porodko indicate that dehydration or flocculation of colloids bears a fundamental relation to chemotropism. Work by Fischer and by Schley indicates similar significant relations between geotropic response and water absorption by colloids (12, 34). To date, however, the results on both chemotropism and geotropism in this line are only suggestive and open the possibility of attacking these complex phenomena of plants on a definite basis of the physics of colloids.

X CONCLUSIONS

In closing let us attempt to make a few summary statements: In discussing the topic colloidal chemistry in relation to biology, one faces a relatively new science with a still newer application to another science. The application to date has been made only at occasional points and not consistently over the whole field. Hence the discussion takes more the nature of isolated illustrations than of a summary, but these illustrations bring into prominence a few very important facts and open up situations of great promise.

The living portion of the organism and many parts produced by it are in the main colloidal and in their behavior obey the laws of colloids. Rational explanations in this field cannot be expected when these basal facts are neglected.

Therefore many of the phenomena of the living organism and some of the phenomena of its environment, which entirely lack explanation on the basis of homogeneous systems, are common processes of colloidal systems.

Although at present the application of colloidal chemistry to biology offers much more of bright prospect and excellent promise than of accomplishment, it is certain that as the application progresses many processes that had to be included under the unexplained group of vital processes will find partial or complete elucidation on the basis of laws of colloids.

But even after colloidal chemistry consummates its possible accomplishments in biology, the vitalist will still have legs, although quite different legs, yet legs to stand upon.

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Papers on Water Supply

EXAMINATION OF DRINKING WATER ON RAILWAY TRAINS

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In order to determine the character of water furnished to the passengers on railway trains, 100 samples from water containers on trains have been collected and analyzed by members of the staff of the Illinois State Water Survey. Although the number of samples examined is small, the information obtained concerning the actual condition of the waters should be valuable in formulating practical standards. The samples were secured from trains at Champaign, Urbana, Kankakee and Chicago. It was thus possible to secure samples from cars coming from all parts of the country.

Of the 101 samples: Twenty-eight of the tanks were said to have been last filled at Chicago. Nine at Peoria. Eight at Centralia. Six at Detroit. Five at Cincinnati. Four at Indianapolis. Three at Kansas City, Mo. Two each at Memphis, Tennessee; Salamanca, New York, and New York City. One each at Boston, Massachusetts; Buffalo, New York; Champaign, Illinois; Dubuque, Iowa; Effingham, Illinois; Forrest, Ill.; Ft. Madison, Ia.; Ft. Wayne, Ind.; Grand Rapids, Mich.; Havana, Ill.; Lincoln, Neb.; Mason City Ia.; Mattoon, Ill.; Minneapolis, Minn.; Montreal, P. Q.; Nashville, Tenn.; Parsons, Kans.; Pittsburgh, Pa.; St. Louis, Mo.; St. Paul, Minn.; Sioux City, Ia.; South Bend Ind.; Springfield, Ill. Four were filled with bottled water from Hammond, La., one with bottled water from Waukesha, Wis. The water in five was of unknown origin. The majority of the samples, 57, were taken from coaches, 19 from sleepers, 8 from dining cars, 7 from smoking cars, 6 from parlor cars, 2 from tourist sleepers, and of 3 there was no record.

The analyses include both bacteriological and chemical examinations and an attempt has been made to make them as complete as possible when using 120 cc. samples for bacterial examination and one liter samples for the chemical tests.

METHODS OF ANALYSIS

The analyses have been made as far as possible in accordance with Standard Methods of Water Analysis of the American Public Health Association (1912) and all analyses made after May 1 include confirmations of *B coli* made in accordance with the recommendations of the Commission on Standards for Common Carriers in Interstate Commerce.

Ninety-nine samples were examined for turbidity. Of these 70 showed a turbidity less than 5 parts per million; 82 less than 10; 69 less than 15, and only 10 showed 15 or more. A turbidity below 10 would not make the water appear unattractive and it would seem not unreasonable to require a standard of 10 or less.

Ninety-nine samples were examined for color. Seventy-nine of the samples had a color less than 5 parts per million; 88 less than 10; 93 less than 20, and only 6 had 20 or more. A color requirement of 20 or less should be easy to meet and it would not be impossible to meet a requirement of 10 or less.

Ninety-nine samples were examined for residue. Of these 28 had a residue less than 50 parts per million; 36 less than 100; 75 less than 200; 84 less than 300; 90 less than 400; 95 less than 500, and only 4 above 500. The very low residues are undoubtedly due to the presence of melting ice in the coolers. The few samples containing more than 500 parts per million would indicate that a standard of 500 or less could easily be made.

Chlorine was determined in 99 samples. Of these 46 had less than 5 parts per million; 66 had less than 10; 75 had less than 15; 82 had less than 20; 90 had less than 25, and only 9 more than 25 parts per million. It should not be difficult to obtain a water containing less than 15 parts of chlorine per million and it should certainly be easy to obtain water containing less than 25 parts per million. In special cases where it is not possible to obtain waters with low mineral content, exceptions to the rule may be made. The same may be true also of residue, magnesium, sulfates, alkalinity and hardness.

Sixty-six were examined for magnesium. Of these 39 contained less than 10 parts per million; 51 less than 15; 60 less than 20, and only 6 more than 20 parts per million. In the large majority of cases, therefore, it should be easy to obtain waters containing less than 20 parts per million of magnesium. If the magnesium were all present as sulfate, 20 parts of magnesium would be equal to 100 parts of magnesium sulfate.

The alkalinity using phenolphthalein and methyl orange as indicators was determined in 99 samples. In only one case was a water found which was alkaline to phenolphthalein. A requirement that the alkalinity of phenolphthalein shall not be greater than one-half the alkalinity to methyl orange would be easy to fulfill and would guard against the use of water over treated with lime. Forty-three samples contained less than 50 parts of alkalinity to methyl orange, 71 less than 100, 89 less than 200. Only 10 had an alkalinity of over 200, and only one of more than 300. A standard of 300 or less would be very easy to maintain and a standard of 200 or less would not be impossible.

The total hardness was determined on 64 samples. Of these 34 had a total hardness of less than 50; 45 less than 100; 57 less than 200. Only 7 had a hardness of more than 200, and but 2 a hardness of more than 300. A limit of 300 would be very easy to maintain and it should not be difficult to obtain waters containing less than 200.

Sixty-six waters were examined for sulfates. Thirty-six waters contained than 10 parts per million of SO_4; 42 less than 25; 54 less than 50; 63 less than 100, and only 3 more than 100. It should be apparently very easy to furnish waters having less than 100 parts per million of sulfates.

Ninety-nine samples were examined for iron. Eighty-six of these contained less than .5 parts per million of Fe; 94 less than 1.0; and only 5 had more than 2 parts per million. A standard of less than 1 part per million would be very easy to maintain and it would not be unreasonable to ask for .5 parts.

Sixty-six samples were examined for lead and copper. Fifty-six of these showed no trace of either metal; 7 contained .1 part per million; 2 contained .2, and 1 contained .3. It would not seem difficult to maintain a standard of less than .3 or even less than .1 part per million.

One hundred samples were plated on gelatin and the number of colonies counted at the end of 48 hours. Of these, 29 samples had less than 99; 16 samples from 100 to 499; 16 from 500 to 999; 9 from 1,000 to 1,000; 9 from 2,000 to 9,999, and 21 more than 10,000.

One hundred and two samples were plated on agar and incubated at 37½° for 24 hours. Forty samples showed less than 50 bacteria per cc; 7 from 50 to 99; 8 from 100 to 199; 14 from 200 to 499; 8 from 500 to 999; 10 from 1,000 to 1,999; 10 from 2,000 to 9,999, and 5 had more than 10,000.

While the large number of bacteria may consist for the most part of harmless forms, the results would indicate unsatisfactory conditions, either in the original water taken or in the conditions of storage and delivery.

The Commission on Standards have made no recommendation concerning the use of gelatin, but their standard of less than 100 growing on agar would mean that 53 per cent of the waters examined were unsatisfactory.

One hundred and nine positive tests for gas formation were obtained in 67 samples examined after May 1. Ninety-one, or 83 per cent of these were shown by the confirmatory tests to contain *B. coli.*

Twenty of the 67 waters were shown to be unsatisfactory by both standard for *B. coli* and agar count of the Commission on Standards of Purity for Common Carriers. Four more did not conform to the *B. coli* standard alone and 24 more did not conform to the agar count standard, making a total of 49 of 67 samples or 73 per cent which did not conform to the standards set by the Commission.

While our methods differ from Creel (Hygienic Laboratory Bulletin 100, 43-57), the results judged by the *B. coli* standard are similar, showing that a better water is found on sleeping cars and parlor cars and the poorer water is found on coaches and smoking cars.

Mr. W. W. Hanford of the Illinois State Water Survey is making a study of the character of the water supplied to railway trains from points in Illinois. As time permits we expect to make more analyses of samples of water taken from trains. An improvement is to be expected as the railway officials are endeavoring to improve conditions as rapidly as possible.

Credit must be given to the members of the laboratory staff of the Illinois State Water Survey for the work which is described in this article.

(A table showing the results of the 102 analyses is published in the Journal of the American Water Works Association for March, 1915, and in Bulletin 12 of the Illinois State Water Survey.)

THE ARSENIC CONTENT OF FILTER ALUM USED BY ILLINOIS WATER PURIFICATION PLANTS

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Introduction

Specifications requiring arsenic free alum for water treatment by several European[1] purification plants suggested to us that it would be advisable to make determinations of the arsenic content of the filter alum used in the State of Illinois.

It is well known that products which are manufactured with the aid of commercial sulfuric acid quite generally contain more or less arsenic, depending upon the purity of the acid used. The poisonous character of arsenic compounds, even when present in small amounts, makes it of general interest and importance to have definite knowledge of the presence or absence of arsenic in any substance which enters directly or indirectly into foods or drinks. Sulfuric acid is used in the manufacture of filter alum and it is thus quite essential, particularly to those who are in public health work, to know whether arsenic in any considerable amounts is being added to drinking water in the process of purification with alum.

We have not been able to learn that anything has been done in this country to regulate the amount of arsenic in filter alum. The purification plants (at least in this State) have made no effort to obtain an arsenic free article. The manufacturers of alum keep more or less accurate records of the arsenic content of their product, but we have found no published records. We have found only one producer who advertises "arsenic free alum." Neither the government nor any of the States have promulgated legislation regulating this product, although there is a regulation concerning arsenic in other substances entering into foods. The government has set a limit for arsenic in coal tar dyes and in baking powder of one part in 700,000. This very low limit, particularly when it is considered that only relatively small amounts of these substances are used in food preparation, shows that considerable importance is attached to the presence of arsenic and its compounds.

Samples: In order that our results might be of greatest value by showing the condition of the alums as they are actually used, we obtained as many samples as possible directly from the various purification plants in the state. Twenty-six plants use alum in treating the water. The purpose of our investiga-

1. Jour. f. Gasbel: 1913 (Sept.)

tion was explained to the managers of each plant. They were asked to co-operate with us by furnishing a sample of the alum used, together with the name of the manufacturer or dealer supplying the same. Twenty-one of the plants very promptly complied with our request, and in nearly every case, expressed decided interest in the subject with a wish to know the results of our investigation. The specimens of alum were carefully sampled, ground and analyzed in duplicate by the following methods:

Methods of Analysis: The method used in obtaining most of the data given is a modified Gutzeit Method, developed by Claude R. Smith[1] in his work on coal tar dyes and other food constituents. The results obtained by this method were in several cases checked by the Marsh-Bezelius Method[2] and were found to agree. The Gutzeit Method has been investigated by others for quantitative work, and, when proper care is taken in the manipulation, has been found to give satisfactory results. The chief modification proposed by Smith is the use of paper sensitized with mercuric bromide in the place of mercuric chloride, which had previously been generally used. The bromide gives more permanent stains and the standards can be kept longer. The method depends upon the formation of a dark orange stain when the generated arsine is brought in contact with the sensitized paper. Under uniform conditions, the length of the stain varies with the amount of arsenic present. A series of standard stains prepared from known amounts of arsenic are used for comparison. A convenient series is made from 2, 5, 7.5, 10, and 15 micro milligrams. The amount of arsenic in the weight of alum taken is determined by matching the stain it produces with the standards; it is then a matter of simple calculation to determine the percentage arsenic content or the parts per million of arsenic. A one gram sample will contain as many parts per million of arsenic as there are micro milligrams of stain obtained. For example, if one gram of alum produces a stain which matches the 5 micro milligram standard stain, then that alum contains 5 parts per million. One part per million is equivalent to .0001 of one per cent. A stain representing between five and twenty-five milligrams gives the most satisfactory results. A stain between these limits can be obtained by varying the weight of alum used.

Experiments: Preliminary qualitative tests were run on several samples of alum that were in the laboratory. All were

1. U. S. Dept. Agr. Bur. of Chem., Circular No. 102.
2. U. S. Dept. Agr., Bur. of Chem., Circular No. 99.

found to contain arsenic, but apparently in rather small amounts.

The results from the samples obtained from the purification plants are given in a table. In all cases the arsenic is recorded as arsenic trioxide, As_2O_3. Five gram samples of the alum were used, as this amount gave stains best suited for comparison with the standards. Quincy and the Rock Island Arsenal each submitted samples from two different manufacturers, therefore twenty-three samples from twenty-one places were examined.

TABLE I.

ARSENIC AS As_2O_3 IN FILTER ALUMS USED IN ILLINOIS

	Arsenic as As_2O_3		
City	Pts. per mil	Percent	Gallons*
Cairo	1.6	.00016	3213
Carlinville	1.8	.00018	2856
Charleston	1.2	.00012	4283
Chicago and Rogers Park	1.4	.00014	3671
E. St. Louis and Granite City	.8	.00008	6425
Decatur	1.4	.00014	3671
Elgin	1.6	.00016	3213
Ft. Sheridan	1.2	.00012	4283
Hamilton	1.4	.00014	3671
Kankakee	.8	.00008	6425
Kenilworth	1.4	.00014	3671
Lawrenceville	3.0	.00030	1713
Macomb	1.6	.00016	3213
Moline	1.0	.00010	5140
Mt. Carmel	2.0	.00020	2570
Mt. Vernon	1.2	.00012	4283
Pana	1.2	.00012	4283
Quincy	1.0	.00010	5140
Quincy	4.0	.00040	1285
Rock Island	2.0	.00020	2570
Rock Island Arsenal	1.6	.00016	3213
Rock Island Arsenal	1.0	.00010	5140
Streator	3.4	.00034	1512

*Gallons of water containing a minimum medicinal dose of 2 mg. when the water is treated with 6 grains of alum per gallon, provided that all the arsenic remains in solution.

The results obtained by analyzing alum used in Illinois clearly show that arsenic in exceedingly small amounts is always present in filter alums. We find a minimum of 0.8 parts per million (.00008 per cent) and a maximum of 4.0 parts per million (.0004 per cent) of arsenic as As_2O_3 in the alum used by Illinois water purification plants. If a water were treated with alum containing the maximum amount of arsenic found at a rate of 6 grains of alum per gallon, an amount which is very seldom exceeded, and if all the arsenic were soluble and remained in the filtered water, since arsenic is not an accumulative poison, a person must drink 1285 gallons of the treated water at one time to obtain a medicinal dose of 2 milligrams. From this it is readily seen that the arsenic content of filter alums used in Illinois is of no significance.

All alums used in this State are supplied by western manufacturers. Several samples have been obtained from the East. In some of these the arsenic content is much higher than that of the Illinois alums. This matter is being investigated further and will be reported later.

THE LONGEVITY OF *BACILLUS COLI* AND *BACILLUS TYPHOSUS* IN WATER

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It has long been known that in natural water there is a tendency of the intestinal bacteria to die out, but very little is known concerning the conditions which govern their death rate. The available data on the subject deal mostly with streams and reservoirs and are influenced by several variable conditions. Very few data are to be found dealing with pure cultures of bacteria and with known conditions of light, temperature, food supply, dissolved oxygen and the presence or absence of other micro organisms.

Most of the published data on the death rate of bacteria refer to death by drying or by disinfectants. The best work has been by Madsen and Nyman[1], Paul[2], Harriett Chick[3], and Eijkman[4]. Their results show a constant rate of death. When the logarithms of the number of bacteria present are plotted against the time, a fairly straight line results. This is the curve of the monomolecular law and was first noted by Madsen and Nyman and lated used by Harriett Chick, who determined constants for all of her data.

All of our work was done with pure cultures of *B. Coli* and *B. typhosus,* kept constantly fresh and vigorous by daily transfers in one per cent lactose broth. When the culture was to be used, smears were made on agar plates and grown for 12 hours, then suspended in sterile water and suitable portions of the suspension used. This method is better than that of using broth cultures for inoculation as only a minimum amount

1. Madsen and Nyman. Beit. f. Hyg. 57, 388, 1907.
2. Paul. Biochem. Zeit., 29, 202 and 249, 1910.
3. Chick. Jour. of Hygiene, 10, 237, 1910.
4. Eijkman, Verslag. der kon. Akad. Wetenschaffen, V. 21, 1, 510, 1912.

of food material is transferred.

All samples of water used were sterilized before inoculation, the samples kept in hydrogen and nitrogen being in filter flasks, the gas entering through the side tube and escaping through a capillary tube at the top. The other samples were kept in Erlenmeyer flasks.

Table I gives the results of *B. coli* in several waters. The constant k is obtained from the formula:

$$k=\frac{1}{t} \qquad \ln\frac{N}{n}$$

t being time, ln the natural log., N the original number of bacteria and n the final number.

TABLE I.

Death rate of B. coli in various waters.

Hours	Redist. N Free Count	K	Dist. H_2O Count	K	Well Water Count	K	Tap Water U. of I. Count
0	1,104,000		212,000		1,920,000		1,500,000
2	4,000	2.809)	19,000	(1.205)	500,000	.672	2,209,000
12	1,000	.583	16,000	.215	3,000	.528	1,360,000
24	200	.358	200	.290	200	.381	1,280,000
48	5	.256			1	.301	
72			3	.159			
96							2,650,000
6 days							2,400,000
37 days							730,000
Average		.399		.221		.470	

The deep well water was quite high in mineral matter, especially nitrates, but contained only a trace of organic matter.

Table II shows the effect of absence of oxygen on *B. Coli.* The cultures were incubated in atmospheres of nitrogen and hydrogen.

TABLE II.

B. Coli in Air, Nitrogen and Hydrogen

	1						2					
	A		N		H		A		N		H	
Time	Count	K	Count	K	Count	K	Count	K	Count	K	Count	K
0	4,000,000		4,000,000		4,000,000		2,800,000		3,350,000		2,700,000	
1.5	3,100,000	(.169)	2,880,000	.219	2,300,000	.368	1,460,000	.434	2,750,000	(.131)	2,000,000	.200
6	450,000	.364	1,760,000	.137	760,000	.277	57,000	.649	2,250,000	.066	385,000	.324
11	50,000	.398	530,000	.184	28,000	.451	10,000	.469	1,650,000	.059	170,000	.230
24	600	.352	95,000	.155	4,500	.271	3,000	.285	520,000	.077	10,000	.233
36	7	.368	50,000	.121	1,300	.223	1,500	.209	320,000	.065	3,600	.184
48	0	.317	30,000	.102	0	.317			160,000	.063	700	.172
72							960	.111	64,000	.055	400	.108
Aver.		.360		.153		.318		.359		.064		.207

TABLE III.

B. typhosus at different temperatures

	1						2					
	8°		20°		37°		8°		20°		37°	
Time	Count	K	Count	K	Count	K	Count	K	Count	K	Count	K
0	195,00		118,000		110,000		93,000		83,000			
2	10,000	1.485	7,500	1.377	500	2.701			10,000	1.057		
4	2,100	1.035	500	1.365	20	1.806	2,200	.936	800	1.160		sample
6	1,325	.832	280	1.007	0	1.934	725	.809	1,550	.663		
8	950	.665	230	.779			300	.718	370	.676	contaminated	
10	500	.596	150	.666			265	.586	300	.562		
12			30	.689			130	.548	90	.569		
14	470	.430	30	.591			60	.524	35	.555		
24	60	.336	2	.458			10	.381	0	.471		
Aver.		.768		.866		2.147		.643		.714		

Nitrogen free water was used for the temperature tests. The constants for air are very good but those for nitrogen and hydrogen are variable but always less than for air showing a slower death rate. No reason for this variation was found.

Only a small amount of work was done with *B. typhosus.* The results obtained were very erratic. The technic was the same as was used for *B. Coli.*

It was impossible to obtain good, uniform constants within each set of counts. The averages of different sets were so far apart that no comparison was possible. One possible explanation is that the stock cultures were kept at 20° and the agar plate which was used to furnish the suspension was incubated at 37° for 12 hours. This sudden change may have weakened some cells to such an extent that uniformity was destroyed.

In general, the *B. typhosus* results was similar to those of Whipple and Mayer[1] and Ruediger[2].

The death rate was higher in nitrogen than in air and the rate increased with a rise in temperature.

CONCLUSIONS

Cultures can be kept uniform for several weeks by daily transfers and by keeping them at the same temperature.

In pure, natural water and in redistilled water *B coli* and *B. typhosus* die from starvation in the gradual regular manner observed in other causes of death.

Within the limits of temperature studied, 8° to 37°. the rate of death increased with a rise in temperature.

The death is similar to a chemical reaction and follows the monomolecular law.

The presence of mineral matter has no apparent effect on the organisms.

The presence of oxygen under starvation conditions seems to be harmful to *B. coli* and beneficial to *B. typhosus.*

This work was carried on under the direction of Doctor Otto Rahn of the Bacteriology Department of the University of Illinois and was done in the laboratories of the Illinois State Water Survey.

1. Whipple and Mayer. Public Health Reports, Vo. 32; Part 2, 76, 1905.
2. Ruediger. Am. J. Pub. Health, 1, 6, 411, 1911.

MANGANESE IN ILLINOIS WATER SUPPLIES

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The presence of manganese in water supplies, except in concentrations so low as to be insignificant, has always been considered rather unusual. This is true particularly in the United States. In Europe, however, manganese in water supplies has been encountered in a number of instances.

R. S. Weston[1] cites some twenty ground water supplies in this country and in Europe, which have been reported as containing manganese:

Locality	Manganese (parts per million)
Arad, Hungary	present
Babylon, N. Y.	0.07
Bayshore, N. Y.	0.37
Berlin, Germany	present
Björnstorp, Sweden	3.4-43.4
Brunswick, Germany	present
Breslau, Germany	trace—110
Calverton, N. Y.	.30
Halle, Germany	1.50
Hamburg, Hofbrünnen	.45
Hanover, Germany	present
Patchogue, N. Y.	.20
Reading, Mass.	.004-0.56
Stargard, Germany	present
Stettin, Germany	5.22
Superior, Wisconsin	.12
Shrewsbury, Mass.	.10

The first instance in this country where manganese was found in sufficient quantity to cause trouble was in the case of the well water supply of a New England mill in 1898[2]. This supply was abandoned because of the high manganese content.

Some sixty-two springs in the United States are mentioned by W. P. Mason[3] as having been reported to contain manganese. Mason states, however, that in nearly half of these the element occurs in traces, and only in seven instances does the amount equal or exceed the content of 4.5 parts per million which he found in the case of a mineral spring at Excelsior Springs, Mo.

Manganese determinations are not made in the general routine work of water laboratories, because the occurrence of the element in water has been considered rather unusual.

1. Trans. Am. Soc. C. E. 64, 124.
2. Trans. Am. Soc. C. E. 64, 124.
3. Chem. News, 61, 123.

Locality	Manganese	Iron	Residue	Source	Remarks
Abingdon, Knox	.00	.0	1323	1350 ft. well	St. Peter
Aledo, Mercer	.00	.0	2078	3165 ft. well	Potsdam
Amboy, Lee	.00	1.4	450	2400 ft. well	, Potsdam
Anna, Union	.00	.0	347	650 ft. well	Limestone
Anna State Hospital, Union	1.3-7.5*	.1-.6*	170-214*	Impounding reservoir	
Anna State Hospital, Union	.05-.2*	1.0*	290*	Wilson Creek	
Arlington Heights, Cook	.00	.2	751	125 ft. well	Glacial drift
Arthur, Moultrie	.00	2.2	491	75 ft. well	Glacial drift
Aurora, Kane	.00	.4	2198	2000 ft. well	Potsdam
Barrington, Cook	.00	.4	397	325 ft. well	Limestone
Bellwood, Cook	.00	1.0	546	1400 ft. well	St. Peter
Belvidere, Boone	.00	.0	511	1800 ft. well	Potsdam
Benton, Franklin	.12	3.5	282	Impounding reservoir	
Bloomington, McLean	.00	.1	768	100 ft. wells	Glacial drift
Blue Island, Cook	.00	.2	1246	1800 ft.-2000 ft. wells	Potsdam
Braidwood, Will	.08	.3	492	20 ft. wells	
Byron, Ogle	.00	.0	288	2000 ft. well	Potsdam
Cairo, Alexander	.00	.1	240	Ohio river	
Carbondale, Jackson	.00	.4	3395	610 ft. well	
Carbondale, Jackson	.00	.1	2198	410 ft. well	
Carbon Hill, Grundy	.00	.8	1295	1800 ft. well	Potsdam
Chadwick, Carroll	.00	.3	399	600 ft. well	St. Peter
Chenoa, McLean	.00	1.1	1298	2100 ft. well	
Chicago, Cook	.00	.0	151	Lake Michigan	
Chillicothe, Peoria	.00	.3	504	35 ft. well	Alluvial
Crystal Lake, McHenry	.00	.06	444	32 ft. well	
Cuba, Fulton	.00	.4	2548	1765 ft. well	St. Peter
Danvers, McLean	.00	1.6	548	211 ft. well	
Danville, Vermillion	.00	.0	454	Vermilion River	
Decatur, Macon	.00	.0	375	Sangamon River	
DuQuoin, Perry	1.50	.2	1066	30 ft. well	
DuQuoin, Perry	.24	.1	1160	Abandoned coal mine	
E. Dubuque, Jo Daviess	.00	.2	278	940 ft. wells	Potsdam

Locality	Manganese	Iron	Residue	Source	Remarks
Edwardsville, Madison	.50	1.8	252	55 ft.-80 ft. wells	Alluvial drift
Effingham, Effingham	.00	.1	235	Little Wabash River	
Elgin, Kane	.10	3.2	377	1300 ft. wells, (Nos. 2, 4)	St. Peter
Elgin, Kane	.00	.4	493	1300 ft. well (No. 3)	St. Peter
Elgin, Kane	.08	.8	380	2000 ft. well (No. 1)	Potsdam
Elmwood, Peoria	.00	.7	1488	1300 ft. wells	St. Peter
Eureka, Woodford	.08	3.0	719	90 ft. wells	Glacial drift
Fairfield, Wayne	.00	.4	905	200 ft. wells	
Farmington, Fulton	.00	.3	1595	1465 ft. wells	St. Peter
Flora, Clay	.08	.0	145	240 ft. wells	
Forest Park, Cook	.00	.0	530	1668 ft.-2015 ft. wells	Potsdam
Forreston, Ogle	.00	.0	610	300 ft. wells	Limestone
Galesburg, Knox	.00	.0	1515	1240 ft. wells	St. Peter
Genoa, DeKalb	.00	.0	315	1500 ft. wells	St. Peter
Gibson City, Ford	.04	.1	320	55 ft. wells	Glacial drift
Grand Ridge, LaSalle	.12	.8	328	196 ft. wells	Glacial drift
Greenup, Cumberland	.00	.05	681	Embarrass river	
Greenview, Menard	.50	1.0	655	80 ft. well	Glacial drift
Hamilton, Hancock	.00	.0	274	Mississippi River	
Havana, Mason	.08	.0	202	75 ft. wells	Alluvial drift
Henry, Marshall	.00	.0	520	1355 ft. wells	St. Peter
Highland Park, Lake	.00	.05	140	Lake Michigan	
Hinckley, DeKalb	.00	.7	340	675 ft. wells	St. Peter
Ipava, Fulton	.00	.0	2977	1575 ft. wells	St. Peter
Jacksonville, Morgan	.00	1.7	515	#1 well	
Jacksonville, Morgan	.00	2.0	424	#4 well	
Jacksonville, Morgan	.00	1.8	372	#5 well	
Jacksonville, Morgan	.00	1.6	1041	Morgan Lake	
Jerseyville, Jersey	.00	.1	328	1542 ft. well	St. Peter
Kankakee, Kankakee	.20	.1	426	Kankakee River	
Keithsburg, Mercer	.16	.3	1262	50 ft. well	
Lacon, Marshall	.00	.0	400	50 ft. well	Alluvial drift
LaHarpe, Hancock	.12	10.0	515	43 ft.-63 ft. well	Glacial drift

Locality	Manganese	Iron	Residue	Source	Remarks
Lawrenceville, Lawrence	.00	.1	1054	Embarrass river	
Leland, LaSalle	.00	4.8	337	230 ft. well	
Lena, Stephenson	.00	.0	497	600 ft. well	St. Peter
Lexington, McLean	.00	1.0	400	115 ft. well	Glacial drift
Mansfield, Piatt	.04	2.1	390	214 ft. well	Glacial drift
Manteno, Kankakee	.00	.4	678	60 ft. well	Limestone
Marengo, McHenry	.04	.1	392	14 ft. well	
Marion, Williamson	.04	.6	1801	#1 700 ft. well	Limestone
Marion, Williamson	.00	.4	1110	#3 700 ft. well	Limestone
Marion, Williamson	.04	.2	1127	#4 700 ft. well	Limestone
Marion, Williamson	.05	.2	1562	#6 800 ft. well	Limestone
Marion, Williamson	.06	.3	1535	#7 960 ft. well	Limestone
Matteson, Cook	.04	4.0	713	283 ft. well	Limestone
Millstadt, St. Clair	.20	.5	339	600 ft. well	
Minonk, Woodford	.00	.2	2337	1765 ft. well	Potsdam
Morris, Grundy	.00	.0	434	650 ft.-800 ft. wells	
Morrison, Whiteside	.00	.5	293	2048 ft well	Potsdam
Mt. Carmel, Wabash	.00	.05	730	Wabash river	
Mt. Morris, Ogle	.00	.1	500	500 ft. well	Limestone
Mt. Vernon, Jefferson	.12-.8*	.1*	215-367*	Impounding reservoir	
Mt. Vernon, Jefferson	.02		155	Casey Fork	
N. Crystal Lake, McHenry	.00	.3	344	285 ft. well	Limestone
Olney, Richland	.04	.7	145	Fox River	
Oregon, Ogle	.00	.8	285	1600 ft. well	St. Peter
Pecatonica, Winnebago	.00	.1	336	20 ft. well	Limestone
Peoria, Peoria	.16	.0	394	#1 60 ft. well	Alluvial drift
Peoria, Peoria	.44	.0	303	#2 60 ft. well	Alluvial drift
Peoria, Peoria	1.6	.05	302	#3 60 ft. well	Alluvial drift
Peoria, Peoria	.75	.8	270	#4 60 ft. we'l	Alluvial drift
Peoria, Peoria	.75	.6	289	#5 60 ft. well	Alluvial drift
Peoria, Peoria	.08	.0	413	#7 90 ft. well	Alluvial drift
Peru, LaSalle	.00	4.0	1730	1500 ft. well	St. Peter
Pontiac, Livingston	.08	.05	557	Vermilion river	

Locality	Manganese	Iron	Residue	Source	Remarks
Quincy, Adams	.00	.1	250	Mississippi river	
River Forest, Cook	.03	.1	452	1000 ft. wells	St. Peter
Riverside, Cook	.04	.2	891	2000 ft. wells	Potsdam
Roanoke, Woodford	.06	.9	900	30 ft. wells	Glacial drift
Rochelle, Ogle	.00	.1	337	1026 ft. wells	St. Peter
Roseville, Warren	.00	.0-.6	566-1047	1260 ft. wells	St. Peter
Rushville, Schuyler	.24	.2	362	20 ft. wells	Alluvial drift
San Jose, Mason	.08	.0	539	105 ft. wells	
Sheffield, Bureau	.20	.1	505	50 ft. wells	
Springfield, Sangamon	.6	2.0	325	45 ft. wells	Alluvial drift
Springfield, Sangamon	.2	.0	345	Sangamon river	
Spring Valley, Bureau	.00	.1	770	1400 ft. wells	St. Peter
Steger, Will	.00	1.0	465	318 ft. well	
Sycamore, DeKalb	.00	2.2	340	905 ft. well	St. Peter
Tolono, Champaign	.00	1.8	647	140 ft. well	Glacial drift
Toulon, Stark	.00	.01	1147	1465 ft. well	St. Peter
Trenton, Clinton	.00	.3	980	235 ft. well	
Utica, LaSalle	.04	.5	444	225 ft.-350 ft. well	Potsdam
Villa Grove, Douglas	00	.0	1022	235 ft. well	Glacial drift
Warren, Jo Daviess	.00	.1	379	700 ft.-875 ft. wells	St. Peter
Washington, Tazewell	.00	2.4	367	80 ft. -90 ft. wells	Glacial drift
W. Chicago, DuPage	.00	.8	405	322 ft. well	Limestone
Woodstock, McHenry	.00	2.6	403	85 ft. well	
Wyoming, Stark	.00	trace	1047	1557 ft. well	St. Peter

*These figures represent the limits of a number of determinations made at different intervals.

In April, 1911, the attention of the Illinois State Water Survey was called to a serious incrustation which had formed in the city water mains at Mt. Vernon, Illinois.* As a consequence, the pressure had become greatly reduced, and in some places complete stoppage of service pipes had occurred. An examination showed that the incrustation contained a large amount of manganese dioxide. The original water contained 0.7 parts per million of manganese. Later, water supplies in other cities were found to contain manganese. Consequently it seemed advisable to examine samples of water from sources which would be representative of typical supplies in order to obtain further information on this subject.

The results thus far obtained from the examination of the water supplies of the state are shown in the table. The amounts of manganese, iron, and residue on evaporation at 180°C are given, with the locality, the depth of well and the geological stratum penetrated. The words, St. Peter and Potsdam, refer to the series of sandstones known under these names. The samples were in all cases taken at the original sources, and not from the city taps.

One hundred and twenty-three waters from one hundred and three different cities were examined. The results show that the supplies of fifteen of these cities contain more than 0.1 parts per million of manganese, the average of the fifteen being about 0.4 parts per million. It is apparent therefore, that manganese is not unusual in the water supplies of Illinois.

No manganese was found in ten of the waters from the thirteen wells which penetrate the Potsdam sandstone. The remaining three contained very small amounts, 0.8 parts per million in a well at Elgin, .04 at Riverside, and .04 at Utica. No manganese was found in twenty-three of the waters from twenty-five wells which reach the St. Peter sandstone. The other two contained small amounts, .10 parts per million in water from a well at Elgin, and .03 parts in a well at River Forest. The two wells at Elgin which show the high manganese content are cased to a depth of less than 100 feet, and may be drawing water from upper strata. Manganese, then is not usually found in waters from deep wells in the sandstones.

Ten of twelve samples examined from wells in alluvial drift contained manganese. The average content of the ten was .52 parts per million. Manganese is, then, very frequently present in wells in alluvial drift.

*Univ. of Ill. Bull., Waterway Survey Series No. 10, 52-57, 57-65. Proc. Ill. Water Supply Assn. 1912, 202-8, 209-12.

The three samples from impounding reservoirs in southern Illinois all contained more than 0.1 part per million of manganese. One of these contained as much as 7.5 parts per million, on one occasion, the amount varying with the rainfall in a surface water of this character. These reservoirs are fed by small streams and springs. The figures indicate that they frequently contain manganese.

No apparent relation exists between the manganese content, iron content and mineral content as indicated by the total residue on evaporation.

The manganese content of water supply is important from the practical standpoint, on account of the objectionable properties of manganese waters. In many respects they are similar to waters which carry iron. They form black stains on white plumbing fixtures and they turn fabrics which are washed in them a yellow color. They cause serious trouble from incrustation due to the separation of manganese dioxide. At the Anna State Hospital the use of a manganese bearing water has caused a hydrotherapy room, fitted with white enamel, tile walls and fixtures, to become seriously stained.

In conclusion, it may be said that the question of manganese content should not be overlooked in the selection of a water supply in Illinois.

This work was carried out under the direction of Professor Bartow, to whom the writer wishes to express his thanks. The subject is being studied further with reference to the removal as well as the further occurrence and method of determination of the element.

A COMPARISON OF METHODS FOR DETERMINING DISSOLVED OXYGEN IN WATER AND SEWAGE

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Dissolved oxygen determinations are of great value in the control of sewage disposal plants and as an index of the purity of the water in streams. Accuracy is necessary, but ease of manipulation is also of importance. Although numerous methods have been proposed, few have survived the tests of practicability and accuracy. In the last report of the Committee of the American Public Health Association on Standard Methods of Water Analysis, the Winkler method has been chosen as the standard. The Levy method is an optional method of the committee on standard methods of the American Public

Health Association, and has been used to a certain extent, but has the disadvantages of requiring special apparatus and a blank determination in each case. These two methods are practically the only ones in use in this country. A brief description of the chemistry of each method follows.

In the Levy method the sample is collected in a special pipette, into which is introduced an accurately measured quantity of ferrous ammonium sulfate ($FeSO_4(NH_4)_2SO_4$); a solution of sodium hydroxide ($NaOH$) is then added; ferrous hydroxide ($Fe(OH)_2$) is formed and part of this is then oxidized to ferric hydroxide ($Fe(OH)_3$) by the dissolved oxygen present. Sulfuric acid (H_2SO_4) is then added and the remaining ferrous sulfate ($FeSO_4$) is titrated with standard potassium permanganate ($KMnO_4$). An equivalent volume of water is treated with the same volume of reagents, but the sulfuric acid (H_2SO_4) is added first to prevent oxidation. The difference between the titration of the blank and sample will give the amount of ferrous salt oxidized by the dissolved oxygen in the water; the dissolved oxygen content in parts per million may be calculated from this.

In the Winkler method the sample is collected in a glass-stoppered bottle, and solutions of manganous sulfate $MnSO_4$, and a mixture of sodium hydroxide, $NaOH$, and potassium iodide, KI, added. The manganous sulfate and sodium hydroxide form manganous hydroxide, $Mn(OH)_2$; part of this is oxidized to manganese oxy-hydroxide, $MnO(OH)_2$ by the dissolved oxygen present in the water. Then sulfuric acid is added; this dissolves the precipitate and liberates free iodine from the potassium iodide according to the following equation:

$$MnO(OH)_2+2H_2SO_4+2KI=MnSO_4+K_2SO_4+3H_3O+I_2$$

The amount of iodine liberated is proportioned to the amount of dissolved oxygen present; the free iodine is titrated with standard sodium thiosulfate, ($Na_2S_2O_3$), using starch paste as an indicator. Dissolved oxygen is reported in parts per million.

The Levy and Winkler methods have both been checked with the gasometric method on aerated distilled water. The Levy method has sometimes been condemned because it has seemed to give variable results[1]. On the other hand, it has been recommended because it is claimed that nitrites do not affect its accuracy.

1. Chlopin; Arch. f. Hygiene, 32, 294-309, 1898. Tiemann and Preusse; Ber., 12, pp. 1784-5.

The Winkler method checks with the gasometric method with uniformly good results[1]. This method gives high results if nitrites are present in the solution. Organic matter is said to reduce the iodine to some extent. "Standard Methods" reads, "If nitrites be present, correction must be made." This correction is not proportional to the amount of nitrite present since the reaction is catalytic. The first reaction is,

$$HNO_2+HI=H_2O+NO+I.$$

The nitric oxide then combines with oxygen from the air to form nitrous acid again, and this liberates more iodine. Winkler appreciated the fact that the second reaction does not take place until the iodine solution is exposed to the air, and oxidized the nitrous acid quantitatively in the bottle, by forming manganic chloride ($MnCl_3$) before the addition of potassium iodide. In a separate sample the amount of manganic chloride required for the destruction of the nitrous acid (HNO_2) was determined. The equivalent of this amount, in terms of dissolved oxygen, is deducted from the total dissolved oxygen.

Two modifications have been proposed for counteracting the effect of nitrites. The first was proposed by Rideal and Stewart[2]. This modification is based upon the principle that nitrites and organic matter may be oxidized by potassium permanganate in acid solution. A few drops of sulfuric acid are first added, then an excess of permanganate. After allowing the oxidation to proceed for 20 minutes, a strong solution of potassium oxalate ($K_2C_2O_4$) is added; this is followed by the usual Winkler procedure.

The second modification was proposed by Hale-Melia[3] This modification is evidently based upon the principle of the suppression of both nitrite reactions by the suppression of the hydrogen ion concentration. In this modification, after the sample has been acidified in carrying on the usual Winkler procedure, an excess of potassium acetate, $KC_2H_3O_2$, is added. This reacts with the sulfuric acid, as follows:

$$H_2SO_4+2KC_2H_3O_2=2HC_2H_3O_2+K_2SO_4$$

Acetic acid has a low hydrogen ion (H^+) concentration; Hale and Melia claim that the interaction of HNO_2 and KI does not take place under these conditions.

In considering Hale and Melia's modification, Elvove[4] has shown that iodine is destroyed by potassium acetate when

1. Winkler; Ber. 21, 2843-54, 1888. Kisch; Zeit. Angen. Chem., 1891, 105-8. Chlopin; Arch. f. Hyg., 27, 18-33, 1896. Spitta; Arch. f. Hyg., 38, 220, 1900. Birge and Juday; Wis. Sur. Bull., 22, 11-12.
2. Analyst, 26, 141-8.
3. Jour. Ind. and Eng. Chem., Dec. 1913, pp. 978.
4. Bull. 96, U.S. Hyg. Lab. pp. 26.

the sample stands for a long time before titration. If the potassium acetate is added from 15 to 30 minutes before the titration is carried out, the amount reduced is negligible.

As to organic matter, Hale and Melia claim that the iodine is not reduced to an appreciable extent by the organic matter present in mixtures of sewage and water.

The importance of comparing these methods has been realized by the Committee of the Laboratory Section of the American Public Health Association and a subcommittee was appointed in 1914 to undertake a comparative study to determine the accuracy, ease of manipulation and adaptability for laboratory and field work of the four methods. The chairman of the subcommittee, Professor E. B. Phelps, outlined the work for the committee.

In this paper the results and conclusions from my experimental work on these four methods are presented.

EXPERIMENTAL

Distilled water was aerated, and after 24 hours, its dissolved oxygen content was determined by both the Levy and Winkler methods.

Then .2 parts per million as nitrite was added in the form of sodium nitrite ($NaNO_2$) and the Levy Winkler, Hale Melia and Rideal-Stewart determinations made. Three samples were taken for each determination. Enough sodium nitrite was then added to bring the N as nitrite content up to .5 parts per million and the dissolved oxygen was again determined by the four methods. The averages of three determinations are reported in Table I. All except the Levy have been corrected for the volume of reagents introduced, as Winkler[1] claims that the concentrated solutions do not contain any dissolved oxygen. The standard permanganate for use with the Levy method and the standard thiosulfate for the other methods were checked against each other a number of times, and both solutions were found to be correct.

TABLE I.

	Aerated, distilled, H_2O	.2 p.p.m N as nitrite	.5 p.p.m. N as nitrite
Levy	8.23	8.17	8.17
Winkler	7.64	8.00	8.24
Rideal-Stewart		7.90	7.70
Hale-Melia		7.95	7.71

1. Zeit. Anal. Chem., 11, pp. 665.

The Levy values do not increase with nitrite but remain about the same as with distilled water—uniformly higher than the Winkler. The Winkler is .36 p.p.m. high with .2 p.p.m. N as nitrite, .60 p.p.m. high with .5 p.p.m. in N as nitrite Rideal-Stewart and Hale-Melia values are practically the same and check fairly well with the standard Winkler value on the same water, nitrite-free

The same procedure was followed with a second batch of samples with the exception that .5 and 1.0 p.p.m. N as nitrite were added. The results are shown in Table II.

TABLE II.

	Aerated, distilled, H_2O	.5 p.p.m. N as nitrite	1.0 p.p.m. N as nitrite
Levy	8.35	7.95	7.95
Winkler	7.58	7.97	8.79
Rideal-Stewart		7.48	7.56
Hale-Melia		7.84	7.61

Levy values are uniformly higher than the Winkler standard on distilled water. The Winkler is .39 p.p.m. high with .5 p.p.m. N as nitrite, 1.21 p.p.m. high with 1.0 p.p.m. N as nitrite. Rideal-Stewart and Hale-Melia values are approximately the same as the Winkler value on aerated distilled water.

In the next series of experiments 5 per cent and 10 per cent of sewage were added. The results are given in Table III. It must be remembered that the addition of fresh sewage to aerated distilled water reduces the dissolved oxygen content due to oxygen consumption by micro organisms, hence these results are comparable only in each dilution.

TABLE III.

	Aerated, distilled, H_2O	5 pct. sewage	10 pct. sewage
Levy	8.30	8.27	7.73
Winkler	7.95	7.42	6.78
Rideal-Stewart		7.32	6.81
Hale-Melia		7.25	6.65

In the presence of the organic matter of sewage, the Levy values are still considerably higher than the Winkler or its modifications. The Winkler, Rideal-Stewart and Hale-Melia values are all practically the same. Evidently the organic matter has not destroyed iodine to any extent.

This point was studied further, as follows:

Dissolved oxygen was determined in mixtures of nitrite-free sewage and aerated water; the remaining amount of liquid, containing free iodine, was divided into two portions. One portion was kept exposed to the air in beakers, the other portion was kept in stoppered bottles out of contact with air. The results are given in Table IV.

TABLE IV.

Reduction of iodine by organic matter.

Percent Sewage	0	25	50	75	100
Dissolved Oxygen	8.08	5.16	2.41	.053	0.00
Dissolved Oxygen, in closed bottles after standing 1 week	8.00	4.40	1.54	3.30	0.00
Dissolved Oxygen in beakers	0.00 in 1 wk.	0.00 in 2 da.	0.00 in 1 da.	0.00 in ½ da.	

It would seem from this table that organic matter does not reduce iodine to an appreciable extent under the conditions of the Winkler method, in which the iodine solution is kept in closed bottles until ready for titration, and is exposed to the air but a few minutes during titration.

In the next series of experiments .5 p.p.m. N as nitrite and 5 per cent sewage was added. Then, keeping the nitrite constant, the sewage content was increased to 10 per cent. Results are given in Table V.

TABLE V.

	Aerated,	.5 p.p.m. N as nitrite	
	distilled, H_2O	5 pct. sewage	10 pct.sewage
Levy	8.23	7.90	7.60
Winkler	7.55	7.54	6.99
Rideal-Stewart		7.07	6.54
Hale-Melia		7.14	6.47

Finally, 1.0 p.p.m. N as nitrite and 5 per cent sewage was added, then, keeping the nitrite constant, the sewage content was increased to 10 per cent. Results are given in Table VI.

TABLE VI.

	Aerated,	1.0 p.p.m. N as nitrite	
	distilled, H_2O H_2O	5 pct. sewage	10 pct. sewage
Levy	8.95	8.50	7.72
Winkler	7.99	8.36	7.28
Rideal-Stewart		8.36	6.76
Hale-Melia		8.41	6.73

Levy values are invariably higher than any of the others; Winkler values are high in the presence of high nitrites; Rideal-Stewart and Hale-Melia agree very well.

The experiments shown in Tables I, II, III, V, and VI have been duplicated, with similar results, but the tables have not been included in this paper. In all, 300 dissolved oxygen determinations were made.

The general conclusions to be derived from this work are:

1. Levy values are higher than Winkler in practically all cases, except where high nitrites are present.

2. Winkler values are much too high in the presence of high nitrites. Either the Hale-Melia or the Rideal-Stewart modification will give correct results up to 1.0 p.p.m. N as nitrite and 10 per cent sewage. The procedure of the Hale-Melia is so much simpler than that of the Rideal-Stewart that it is much preferable for field work.

It is of interest to note that in a large number of comparative determinations of dissolved oxygen on the Illinois State Water Survey[1] were, on the average, 1.0 parts per million higher than results by the Winkler method used by the Sanitary District of Chicago.

The Levy method was used by the New York Metropolitan Sewerage Commission[2] in its work on New York Harbor. The Winkler method was used by Birge and Juday[3] in their extensive work on Wisconsin lakes. Phelps[4] has used the Rideal-Stewart method in his work on the Ohio River. Lederer[5] uses the Hale-Melia method at the Chicago Sanitary District; it is also used by Hale and Melia[6] at the Mt. Prospect Laboratory, Brooklyn, N. Y. Thus it is seen that a standard method is desirable in order that all results may be comparable. To this end the experiments indicate the advisability of discarding the Levy method, and of officially adopting the Winkler method, with the Hale-Melia modification in the presence of high nitrites.

The experimental work reported in this paper was done in the laboratories of the Illinois State Water Survey in July, 1914.

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1. Unpublished work, Ill. St. Water Survey.
2. Report, N. Y. Met. Sewerage Comm., 1914.
3. Wisconsin Survey Bull. XXII, page 11.
4. Jour. Ind. and Eng. Chem., Aug. 1914, pp. 682.
5. Jour. Ind. and Eng. Chem., Nov. 1914, pp. 884.
6. Jour. Ind. and Eng. Chem., Dec. 1913, pp. 976.

Papers on Geology

Figure 1. A small anticline in a post-glacial valley. Huidekoper's Ravine, Meadville, Pennsylvania.

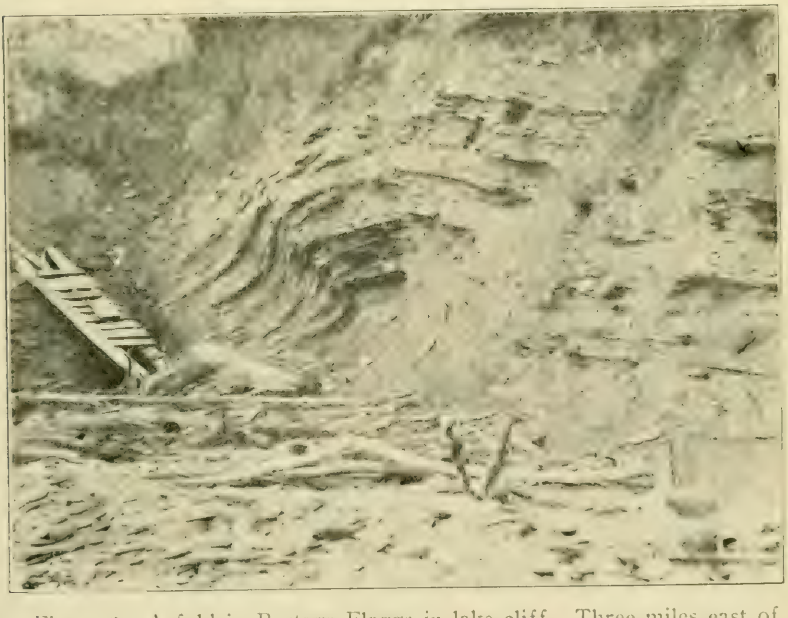

Figure 2. A fold in Portage Flaggs in lake cliff. Three miles east of Erie, Pennsylvania.

RECENT CRUSTAL MOVEMENTS IN THE EASTERN PART OF THE GREAT LAKES REGION

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INTRODUCTION

While in the region of the Great Lakes and along the Atlantic Coast, careful search has been made for even slight vertical movements in recent geological time, little attention has been given to recent tangential movements in either of these areas. The present study has been initiated in the eastern part of the Great Lakes Region to determine the age, distribution, extent, and significance of these tangential movements.

The rocks of northeastern Ohio and northwestern Pennsylvania and New York for the most part appear horizontal. However, a study of their distribution shows a gentle dip toward the southwest[1]. Exceptions to this gentle dip in the way of folds were noted early, and recent study is increasing the number of these exceptions very materially, especially between Cleveland, Ohio, and Westfield, New York.

PREVIOUS STUDY

Hall described and figured some folds in 1843 in northwestern New York[2], and in 1910 Van Horn described some small anticlines in the Chagrin shales near Cleveland, Ohio[3], but neither considered the edge of the folds. Gilbert[4] in 1886 recognized that some folds in northwestern New York were post-glacial, and presented a paper on "Some New Geologic Wrinkles." In 1903 Smallwood and Hopkins[5] described some small anticlines near Meadville, Pennsylvania. While these writers did not specially consider the age of the deformation, recency is implied by the origin assigned for the folds, landslides on the valley walls. However, most of these folds are in no way related to the landslides, and the few that are seem to have no causal relation with them, so an inference of recency because of such relation has little or no force.

AGE OF THE ROCKS

The rocks affected by the disturbances in the area under consideration range in age from Middle Devonian to Lower Mississippian[6].

1. I. C. White: Second Geol. Surv. of Pa., Report Q4, 1881, pp. 44-49.
2. Geol. of Fourth Dist., N. Y., pp. 295-298.
3. Bull. Geo. Soc. America, vol. 21, pp. 771-773.
4. Proc. Amer. Assoc. Adv. Sci., vol. 35, p. 227.
5. Bull. Syracuse Univ., Series IV. No. 1, pp. 18-24.
6. I. C. White, Second Geol. Surv. Pa., Report Q4. pp. 93-119.

CHARACTERISTICS OF THE ROCKS

Shales are the dominant rocks among those exposed in this area. Except for a few sandstones, they are nearly all shales with thin sandstone beds interspersed. The sandstone beds in the shales increase both in number and in thickness in the older formations, so that in the oldest formation, the Portage, flaggy sandstones constitute an important part of the rock, and some of the beds are a foot or more in thickness.

NATURE AND EXTENT OF DEFORMATION

The deformation includes folds and faults. Of the folds there are two types—those with longer axes parallel to the valleys and those with their axes transverse to valleys. These two types are found not together but in different areas. The faults, so far studied, are all thrusts, with possibly one slight exception.

FOLDS PARALLEL TO VALLEYS

The first type of folds noted above consists of small anticlines in the bottoms of valleys that trench the uplands (Fig. 1). These folds involve only a few feet of strata, and rarely affect the walls of the post-glacial valleys in which they are most commonly found. Some of these anticlines are narrow and close, while others are broad and open. They are variable also in length, ranging from a few feet in some instances to over 100 feet in others. While the axes of the folds vary somewhat in direction, most of them trend nearly with the valleys in which they occur. Though the folds seem to have been formed as the valleys developed, no definite evidence of age has been noted in connection with them, and they are small and unimportant when compared with many of the folds of the second type.

FOLDS TRANSVERSE TO VALLEYS

In the second type of folds the axes are chiefly transverse to the valleys, and they affect not only flood-plains, terraces, and walls of valleys, but they occur also in the lake cliffs east of Erie, Pennsylvania. (Fig. 2). Some anticlines occur alone, but frequently several are associated with synclines in a series. These folds commonly involve from 10 to 20 feet, and in some instances 60 to 80 feet, of strata exposed above the stream bed and an unknown amount below it. The folds vary in width from a few feet to over 500 feet. Many folds may be seen distinctly on both sides of a stream.

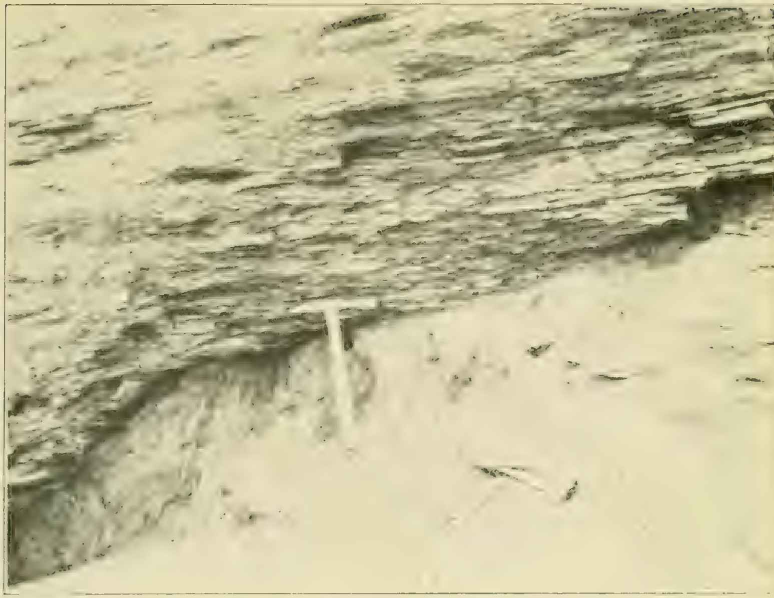

Figure 3. A fault showing brecciated zone with upturned beds still attached to downthrown side. A mile south of Girard, Pennsylvania.

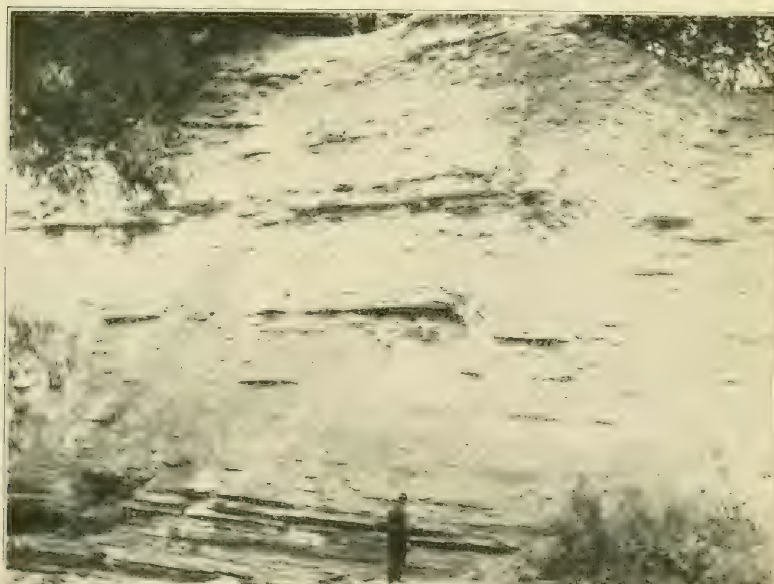

Figure 4. An asymmetrical fold deforming the surface of a forty-foot terrace. A fault below grades into this fold above. Little Elk Creek, five miles south of Girard, Pennsylvania.

THRUST FAULTS

Many of the transverse folds are accompanied by thrust faults. Some faults occur in the middle of an anticline and others at the edge next a syncline. Some faults grade into folds above, others feather out in the loose upper shales, while still others break clear across the strata. Though the displacement of beds is generally less than ten feet, and may be less than a foot, many of the fault planes are marked by distinct brecciated zones. The evidence of overthrust in one of these faults seems very decisive, for the upturned edges of the soft shales are still attached to the ends of the downthrown beds, while the downturned ends on the upthrow side have been broken off and ground fine by the movement of the upthrown rocks over them (Fig 3).

AGE OF FOLDS AND FAULTS

The rocks themselves fix the age of the folds and faults only as later than Devonian or Mississippian, but the relations of these movements to glaciated surfaces, glacial deposits, terraces, and flood-plains, show that many of them are not only post-glacial, but that they are later than the low stream terraces, and that a few of them are even later than the present flood-plains.

The evidence of recency is seen in the rise of the loose top of a fold distinctly above glaciated surfaces on either side (Fig. 2), and in the deformation of glacial deposits above the fold in such a manner that surface drainage has been affected and a recent gully started along the fold parallel to the axis.

Other evidences of recency are found in the deformation of the surface of a terrace by a fold or fault, and in the uneroded condition of the top of fold or fault in a terrace (Fig. 4).

In like manner, the deformation of the surface of a flood-plain by a fold or fault, or the uneroded top of fold or fault in the flood-plain, shows that it is more recent than the flood-plain.

Though not so definite as to time, other evidences of recency are seen in the freshness of the brecciated fault zones and in the unweathered condition of joints near the surface.

CONCLUSIONS

A reconnaisance was made by the writer of parts of the larger streams flowing into Lake Erie from Sandusky, Ohio, eastward to Westfield, New York. While distinct folds of considerable size were found particularly along the Vermilion and Black rivers in northern Ohio, no evidence of recency was found in connection with any of the folds until in the vicinity of Cleveland. From there eastward through northeastern Ohio and northwestern Pennsylvania and New York the rocks have suffered recent deformation in a manner not duplicated in those in adjacent glaciated areas.

Though these movements have not been studied eastward, there is evidence that they extend much farther in that direction, and some of them have been noted on the north side of the lakes as well.

THE LOESS IN ILLINOIS: ITS ORIGIN AND AGE

T. E. Savage, University of Illinois

INTRODUCTION

In spite of the fear that it might appear presumptive to present a paper on the much discussed problem of the loess before this Academy, it seemed to the writer that there is need at this time of a more extended statement than can be made in the ordinary geologic reports of the main facts of the loess deposits and of the interpretation which those facts reasonably support.

The name loess is applied to the fine-grained silt-like deposit that, over portions of Illinois and elsewhere in the Upper Mississippi Valley, lies at and immediately beneath the surface to a variable depth of from 2 or 3 to 50 or more feet. On the hills it is generally yellow, but over the more level, poorly drained areas the soil developed at the top of the loess is colored dark with organic matter to a depth of 1 to 3 feet, below which the color grades through shades of gray to yellowish brown. The deposits rarely show any trace of stratification or lamination, and where cut by streams or excavations it tends to stand for a long time in nearly vertical cliffs. In the dryer places, especially in the thicker deposits on the hills, the loess contains numerous shells of species of air breathing gastropods that now inhabit forest-covered slopes. In its typical development the loess is practically limited to the Mississippi basin and in this region it sustains peculiar relations to certain topographic features and to certain beds of glacial drift.

Figure 8. Moraine-like hills of loess bordering the Iowan drift margin in Tama county, Iowa.

DISTRIBUTION OF THE LOESS

The loess covered area in the Mississippi Valley is chiefly confined to the surface of the older (Kansan and Illinoian) drift sheets and the driftless area, and is mostly included between the Missouri and the Wabash rivers, occurring in its typical characters but a few miles west of the Missouri, and extending east of the Wabash in the vicinity of the Ohio river for several miles east of Cincinnati. South of the Ohio river the loess is chiefly limited to a rather narrow belt adjacent to the Mississippi, nearly to its mouth.

Within this general area the distribution of the loess presents the following significant peculiarities:

1. Except where local topographic features have modified the normal deposition, it is thickest, most typical and most generally fossiliferous on the bluffs bordering the east side of the larger stream valleys, as along the Missouri, Mississippi Illinois, Wabash and smaller rivers, the thickness generally decreasing with increasing distance from the streams. This peculiarity has been noted by all of the students of the loess.

Leverett[1] says that the general thickness of the loess on the east side of the Mississippi Valley from the driftless area southward the entire length of Illinois, is much greater than on the west side in Iowa and Missouri; probably twice as great; and a similar difference exists on the east and west sides of the Valley of the Wabash river.

Shimek[2] says that the bluffs of the Missouri river from Sioux City to Kansas City, and those bordering the Mississippi are higher, with thicker loess deposits on the east side than on the west.

In his report on the St. Louis Quadrangle, Fenneman[3] says that the loess is thickest on the east bluffs of the Mississippi and Missouri rivers where in some places it reaches 50 feet, but it thins to only 10 or 15 feet at a distance of only a few miles.

In many places along the rivers of Illinois as opposite Burlington and below Alton along the Mississippi, the loess has accumulated on the east bluff in dune-like ridges that stand 25 to 50 feet above the uplands farther east, and appear as billowy ridges fringing the east banks of the streams.

1. Frank Leverett: The Illinois Glacial Lobe. Mon. XXXVIII U. S. Geol. Survey, 1899, p. 183.

2. B. Shimek: Loess Papers. Bul. from the Laboratories of Nat. Hist. of the State of Iowa, Vol. V, No. 4, p. 371. Nov. 1904.

3. N. M. Fenneman: Geo. and Mineral Resources of the St. Louis Quadrangle. Bul. No. 438, U. S. Geol. Survey, 1911, p. 33.

2. A belt of moraine-like hills, composed of loess instead of till, borders the Iowan drift sheet in Iowa, as shown in figure 1, and continues as an unusually thick deposit, but with decreasing thickness for a considerable distance south and east of the margin of this drift sheet.

3. The loess is very thin and patchy or entirely absent, over the surface of the younger (Iowan and Wisconsin) drift sheets in all of this region.

4. Over the upland areas of the older (Kansan and Illinoian) drift sheets the loess has its greatest development in Iowa and northern Illinois, where its average thickness is 10 to 15 or more feet. The thickness diminishes notably towards the south and east, being only 1 to 4 feet over the interstream areas in southern Illinois south of the Kaskaskia river, and south of the Wisconsin drift sheet in Illinois, Indiana, and Ohio. In this region of thin loess the deposit is not so homogeneous as it is farther north; in many places the upper 12 to 18 inches being very porous, and of a white, ashy appearance, and often being referred to as "White Clay." Below this white superficial portion the material is brown and much more clayey and compact, and tends to break into small prismatic blocks when dry. This peculiarity is thought to have been developed by the finest particles of the surface loess having been carried downward by ground water, leaving the upper part very porous, but forming a compact deposit where these finer particles became lodged in the small cracks and interstices lower down. The general distribution of the loess in Illinois is shown on the accompanying map. (Plate 1).

COMPOSITION OF THE LOESS

The loess is composed of very small angular undecomposed mineral particles, of which quartz predominates and feldspar, hornblend, calcite, dolomite and other minerals are also common. The texture is usually quite uniform except for occasional pebbles ranging in size to one inch in diameter, which occur in the lower 2 to 5 feet of the deposit. It is thought that these pebbles were not originally deposited with the loess as will be shown later. Some of them are of chert or limestone or sandstone of local origin and others are of crystaline rock. Any kind of pebbles common in the underlying till may occasionally occur in the lower part of the overlying loess, not only on the hills and slopes, but also over the more level areas.

The following table of mechanical analyses of loess from a number of localities shows the texture of the upper part of this deposit in different parts of the state.

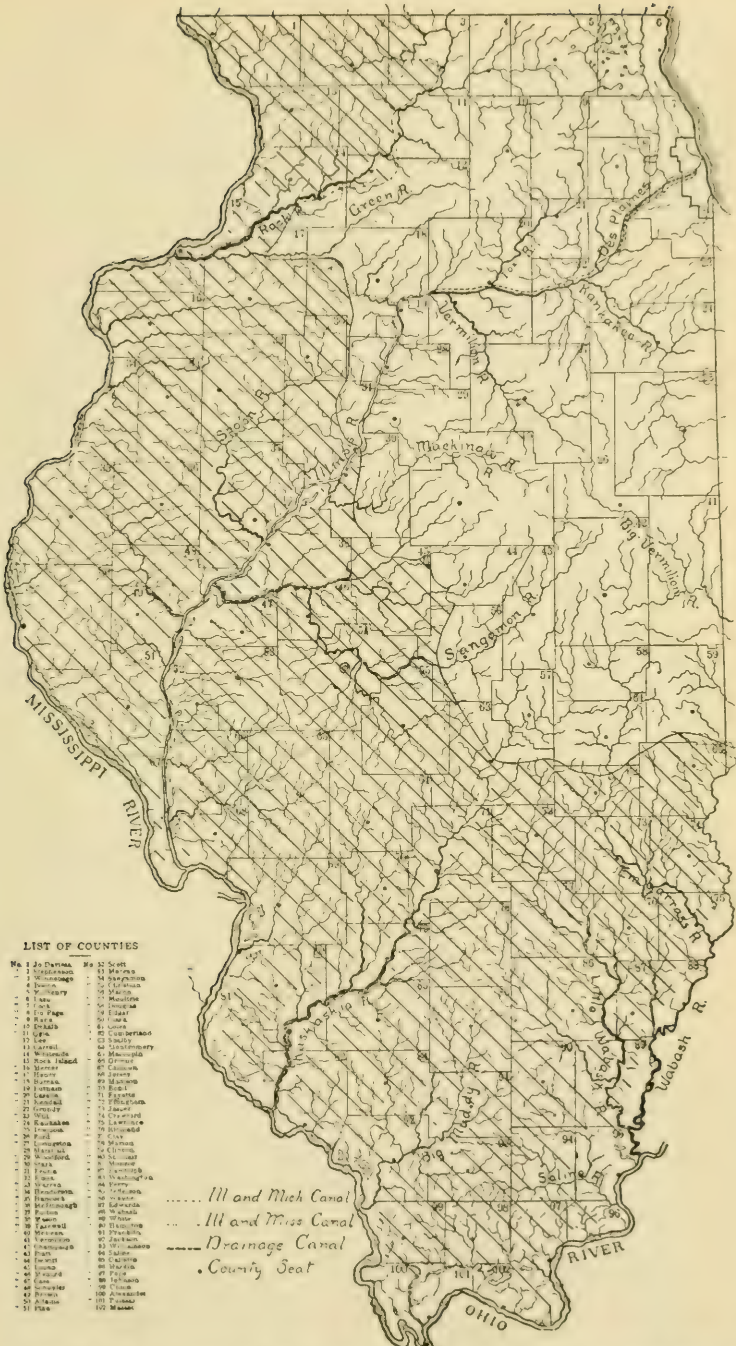

Plate I. Map showing by oblique lines the area of main loess distribution in Illinois.

*MECHANICAL ANALYSIS OF THE LOESS IN ILLINOIS

Diam. in Millimeters	Conventional Name	E. Dubuque 1-15 in.	Rock Island 1-6 in.	Carrollton 1-15	Virginia City 4-48	Near Greenup 2-15 in.	Moweaqua 2-18 in.	Galatea 1-18	Champaign Bowlder Clay 30-42 in.
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
2-1	Fine gravel	0.00	0.00	0.00	0.00	0.30	0.00	0.00	1.04
1-.5	Coarse sand	0.00	0.00	0.00	0.00	1.05	0.08	0.00	1.98
.5-.25	Medium sand	0.04	0.02	0.01	0.00	3.42	0.77	0.02	6.85
.25-.1	Fine sand	0.74	0.17	0.04	0.01	3.30	0.11	0.30	6.23
.1-.05	Very fine sand	30.12	22.27	9.93	7.68	6.47	4.88	5.21	5.82
.05-.01	Silt	41.49	51.53	48.76	61.85	55.48	52.50	57.75	28.38
.01-.005	Fine silt	7.96	9.72	8.39	9.60	11.70	12.15	12.78	15.46
.005-.0001	Clay	14.44	12.08	23.65	15.15	14.90	22.10	20.36	30.00
	Total Mineral Matter	94.79	95.79	93.78	94.29	96.62	92.59	96.42	95.64
	Organic Matter Water Loss	5.21	4.21	6.22	5.71	3.38	6.61	3.58	4.36
	Loss by Direct Ignition	5.66	4.21	6.14	5.87	3.11	5.73	6.01	

* Whitney, Milton: Report on the examination of some soils from Illinois; report of the Illinois Board of World's Fair Commissioners, 1893, pp. 103-106.

From this table it may be seen that the greater part of the loess is composed of particles intermediate in size between sand and clay, but that it grades into sand on the one hand and into clay on the other. The table also shows that the loess in the vicinity of the larger streams, and in western Illinois, contains a larger percentage of coarser particles than that over the uplands some distance from the streams, and in the eastern part of the state. Compared with the drift or bowlder clay, shown in the right hand column, the loess contains a smaller percentage of either the coarse or very fine constituents and a relatively larger percentage of particles of intermediate size.

SOURCE OF THE LOESS MATERIALS

Two sources have been suggested for the materials of the loess. Some geologists have assumed that it has been blown by the winds from the arid regions of the Great Plains, while others think it has been derived from the rock flour of glacial till. The former theory is discredited by the following facts:

1. The small size of the particles of the surface soil of the arid regions. Merrill[4] says "the particles of adobe or surface soil of the Great plains vary in size from those too small for measurement, up to .08 millimeters in diameter. It will be seen from the former table that both the maximum and minimum size of the particles of the loess are larger than those of adobe, which is the opposite of what would be expected if the latter was the source of the loess.

2. The constituents of adobe contain a much larger proportion of calcium carbonate and of mineral matter derived from sedimentary rocks than does the loess.

3. The peculiar distribution of the loess in relation to the drift deposits of the upper Mississippi Valley. Chamberlin says, "The constitution of the loess of the Mississippi Valley taken with its two distributive relationships proves it to have a special origin from the glacial drift."

4. Adobe soil is much more variable in its chemical composition than the loess, as appears in the following comparative table of analyses in which columns 1 to 5 show the analyses of loess from different localities, and columns 6 and 7 are those of adobe soil.

The peculiar relations of the loess to the various drift sheets and to the streams of the glaciated region and the rseemblance of the loess in freshness and mineral composition to the finer parts of the till, furnish convincing evidence that the source of the loess material was glacial drift. It also seems reasonable to assume that the belts of greatest thickness of the loess are nearest the immediate sources of supply. If this is true the main immediate sources of the loess are, 1, river flood plains, and 2, the Iowan drift sheet.

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4. George P. Merrill: Rocks, Rock Weathering and Soils; p. 321, 1916.

*TABLE OF ANALYSIS OF LOESS AND ADOBE SOIL

	No. 1 Dubuque	No. 2 Galena	No. 3 Kansas City	No. 4 Vicksburg	No. 5 Near Terra Haute	No. 6 Adobe Santa Fe N-Mex	No. 7 Adobe Salt Lake City, Utah
SiO_2	72.68	64.61	74.46	60.69	79.77	66.69	19.24
Al_2O_3	12.03	10.64	12.26	7.95	9.95	14.16	3.26
Fe_2O_3	3.53	2.61	3.25	2.61	3.39	4.38	1.09
FeO	.96	.51	.12	.67			
TiO_2	.72	.40	.14	.52	.70		
P_2O_5	.23	.06	.09	.13		.29	.23
NnO	.06	.05	.02	.12		.09	Trace
CaO	1.59	5.41	1.69	8.96	.67	2.49	38.94
MgO	1.11	3.69	1.12	4.36	.26	1.28	2.75
Na_2O	1.68	1.35	1.43	1.17	1.08	.57	Trace
K_2O	2.13	2.06	1.83	1.08	2.05	1.21	Trace
H_2O*	2.50	2.05	2.70	1.14	2.55	4.94	1.67
CO_2	.39	6.31	.49	9.63		.77	29.57
SO_3	.51	.11	.06	.12		.41	.53
C (Organic)	.09	.13	.12	.19		2.00	2.96

*Contains H of organic matter in Nos. 1-4.

1. Nos. 1 to 5: Leverett, Frank: The Illinois Glacial Lobe. Mon. XXXVIII, U. S. Geo.. Survey, 1899, p. 164.

Nos. 6 and 7: Clark, F. W.; The Data of Geochemistry. Bul. No. 491, U. S. Geol. Survey, p. 487.

MODE OF ACCUMULATION OF THE LOESS

Orton suggested that the loess or white clay of southwest Ohio represented the fine materials brought up by earth worms and other burrowing animals from the underlying till. That the aggregate work of earth worms is considerable, no one will doubt, but the inadequacy of such agents in the accumulation of the loess will be readily seen in the places where the deposits have a thickness of several feet. It is also shown in the fact that in the same general region there is no perceptible difference in the thickness of the loess whether it is immediately underlain by drift or by such beds as gravel, sand, soil or peat, which contain no fine constituents resembling loess. The clear zone of contact that in most places separates the loess from the underlying bed shows that the disturbance produced by earthworms and other burrowing animals are relatively unimportant as far as loess accumulation is concerned. The indifference in the thickness of the loess to the character of the bed that lies beneath it, as stated above, indicates that the loess could not have been derived from the underlying deposit, but that it was transported, and laid down above the material upon which it rests. The homogeneous, well sorted character of the loess is proof that it has been carried and deposited either by wind or water, for no other geological agent is capable of so thoroughly sorting the material it deposits.

The general distribution of the loess, being thicker and coarser on the hills bordering the larger streams than over interstream areas (see figure 2), and especially thick on the tops of the hills, bordering the windward side of the valleys and around the border of the Iowan drift plain, in Iowa, and towards the north in Iowa and northern Illinois than farther south; the great range of relief shown in the loess deposits, being more than 600 feet in Illinois, and exceeding a thousand feet in the Mississippi basin; the fact that the loess does not tend to level the inequalities of the surface, but mantles the hills, prairies and lowlands; the general lack of stratification or lamination of the deposits; and the presence in the loess of entire shells (many of which are fragile and easily broken) of species of terrestrial gastropods that now live on dry woodland hills, are conclusive evidences that the loess in the Mississippi Valley region was carried and deposited by wind, rather than by water.

Water laid silts are distinguishable from true loess by the greater distinctness and horizontality of their stratification, by the more heterogeneous character of their constituent materials and by the fact that their fossils, when present, are aquatic. If sediments possessing these characters of aqueous deposition were never included under loess deposits, it would tend to clear up and prevent much of the confusion that is now so prevalent concerning the loess. There is no more reason for designating water laid deposits resembling loess in texture, or even derived from loess by the name loess, than there is for applying the name shale to fluviated deposits derived from beds of shale. In geologic mapping all such water laid deposits would be classed as alluvium.

Calvin[8] has pointed out that there are three things to account for in the proper explanation of loess deposition:

1. An extensive gathering ground of bare and dry surfaces as a direct source of the material.

2. An agent of transportation and deposition consistent with the source of supply and the sites of deposition.

3. Obstructions to the transporting agent, such as would result in deposition and lodgment in the places where such deposits now occur.

All the above conditions are completely satisfied in harmony with deposition of the loess by winds. The position of the thicker and coarser loess deposits on the bluffs bordering the windward side of the larger flood plains are in the places where the prevailing westerly winds, after sweeping over exposed

8. Samuel Calvin: The Iowan Drift. Journal of Geology, Vol. XIX, No. 7, 1911, p. 601.

flood plain areas, would have their velocity checked and so be compelled to drop a part of their load on the bordering banks, which then as now, were doubtless forest covered and so furnished lodgment for a part of the silts deposited upon them. A large part of the material would always be carried beyond the bordering hills and finally be dropped upon the interstream areas.

Even the details of thick loess distribution bordering the streams are in harmony with wind deposition, for the thickest loess is not where the winds blow straight across the valleys, but is on the bluffs bordering those portions of the valleys which trend oblique to the prevailing wind currents, so that the winds followed along the valley for some distance before their movements were obstructed by a bend in the channel. This is illustrated by the deposits along the Sangamon river in the Springfield Quadrangle. The deposits of the thick loess around the margin of the Iowan drift sheet and extending with decreasing thickness for many miles to the south and east are also consistently explained only by the agency of the wind The most striking characteristics of the Iowan drift sheet are, 1, the thinness of the drift; 2, the lack of the usual amount of fine material and the presence of great numbers of bowlders upon its surface, and, 3, the moraine like hills of loess bordering the area. All of these peculiarities would be developed as a result of winds blowing outward over the surface of the glacier, or over the dried mud flats of the drift sheet, after the glacier had retreated to the northward, but before a cover of vegetation had become established upon the drift surface. Winds sweeping unchecked over the bare drift surface during dry periods would pick up large quantities of the finer materials. A part of their load would be dropped when the forest that fringed the border of the Iowan drift area was encountered and a part would be carried farther forward. If such conditions attended the withdrawal of the Iowan ice sheet as resulted in the surface of the drift remaining bare of vegetation for a long time, the bowlders and coarser debris of the till would become concentrated at the surface by the removal by the winds of a large part of the finer constituents, reducing by this great amount the thickness of the Iowan drift.

A part of the material gathered by the winds from the river flood plains or from the Iowan drift surface would be dropped at the immediate border, a part would be carried for a longer or shorter distance before finding permanent lodgment in the vegetation that covered the uplands. Another part dropped in places not well protected with vegetation. was doubtless again picked up, together with fine material from other sources and carried forward for some distance and again dropped, and the process was repeated again and again until the fine silt was spread widely over the interstream areas, and much of it is now a long distance from its original source.

SOURCE OF THE PEBBLES IN THE LOESS

Pebbles are rare in the loess, but a few occur in the lower 2 to 5 feet of the deposit over practically all of the loess area, being more frequent where the loess is thin than where it is best developed. The presence of occasional pebbles in the lower part of the loess has been considered by some geologists as evidence of the aqueous origin of at least this portion of the deposit, but it is just as difficult to explain how occasional pebbles could be included in the midst of an otherwise homogeneous, fine grained, unstratified deposit laid down by water as in such a deposit made by wind.

A study of the process of accumulation of the loess now forming over the surface of the early Wisconsin till has furnished valuable information concerning the probable source and manner of inclusion of the pebbles in the lower part of the loess in other regions. The higher portions of the surface of the early Wisconsin till in Champaign county are in places covered with 1 to 3 feet of porous, fine grained, loess-like material which, like the loess in other places in the State, is largely composed of minute, fresh, angular fragments of quartz, feldspar, hornblende, and other minerals derived from igneous rocks. In this recent loess small pebbles are somewhat more numerous than in the lower part of thicker loess deposits over the Illinoian and Kansan drift sheets, probably on account of the slower rate of accumulation of the loess now forming on the Wisconsin drift, compared with the rate at which the loess accumulated in early Peorian time.

Over the more dry, uncultivated areas of this surface burrows of ground squirrels and other animals are common. Many of these burrows pass through the thin loess mantle into the unlerlying till, and the dirt thrown out around the tops of the holes often contains a few small pebbles. In poorly drained areas crayfish holes are in places almost as numerous as the burrows on the higher lands. In the craters built up around the tops of these holes a few pebbles ranging in size up to one inch in diameter were collected. Pebbles are also occasionally carried from areas where no loess is present to areas where loess is accumulating in the mud on the feet of hoofed animals.

In all of these ways occasional pebbles are now being scattered on the surface of, and becoming imbedded in, the loess accumulating upon the Wisconsin till, but each of these agencies gradually becomes less effective and will eventually fail to scatter any pebbles, as the thickness of the loess increases. It is believed that by means similar to the above the pebbles became incorporated in the lower part of the loess deposit as it was in process of accumulation over the main loess covered regions.

RELIEF OF THE PRE-LOESSIAL SURFACE

The relief of the surface of the Illinoian drift sheet at the time the loess was laid down upon it was worked out in detail in the Avon and Canton quadrangles in the northcentral part of the State where the loess is well developed. This was determined by finding the elevation of the upper surface of the drift, and thus of the lower surface of the loess at a large number of places where the contact was exposed as shown on the map, (plate 2). The relief of the surface of the drift beneath the loess in the Canton quadrangle was found to exceed 150 feet, and the general slope of the top of the drift beneath the loess in this region was found to correspond in a general way to the slope of the present surface. The main divides of the region at the time the loess was deposited were the same as at present. In the Canton quadrangle the main highland which then, as now, lay between Farmington and Norris, extended a little south of west past the town of Fairview. From this highland the pre-loessial surface declined southward along Copperas Creek as much as 100 feet in a distance of 6 miles. Along Big Creek, from its sources in the vicinity of Norris to the town of St. David, the total difference in the elevation of the drift surface beneath the loess exceeds 125 feet. From the headwaters of Put Creek to the place where it leaves the quadrangle near the southwest corner, the surface declines more than 100 feet. A like difference in the altitude of the upper surface of the drift is shown between the head waters of Turkey Creek and Coal Creek and the top of the drift bordering these streams at the west side of the quadrangle. From the sources of Littlers Creek to its junction with Spaan River the pre-loessial drift surface declined 150 feet.

The topography of the Illinoian drift surface beneath the loess in the Avon quadrangle resembles that of the Canton quadrangle described above, as does also the pre-loessial surface of the drift in the Sumner and Hardinville quadrangles in Southeastern Illinois, and the Herrin quadrangle in the southern part of the state.

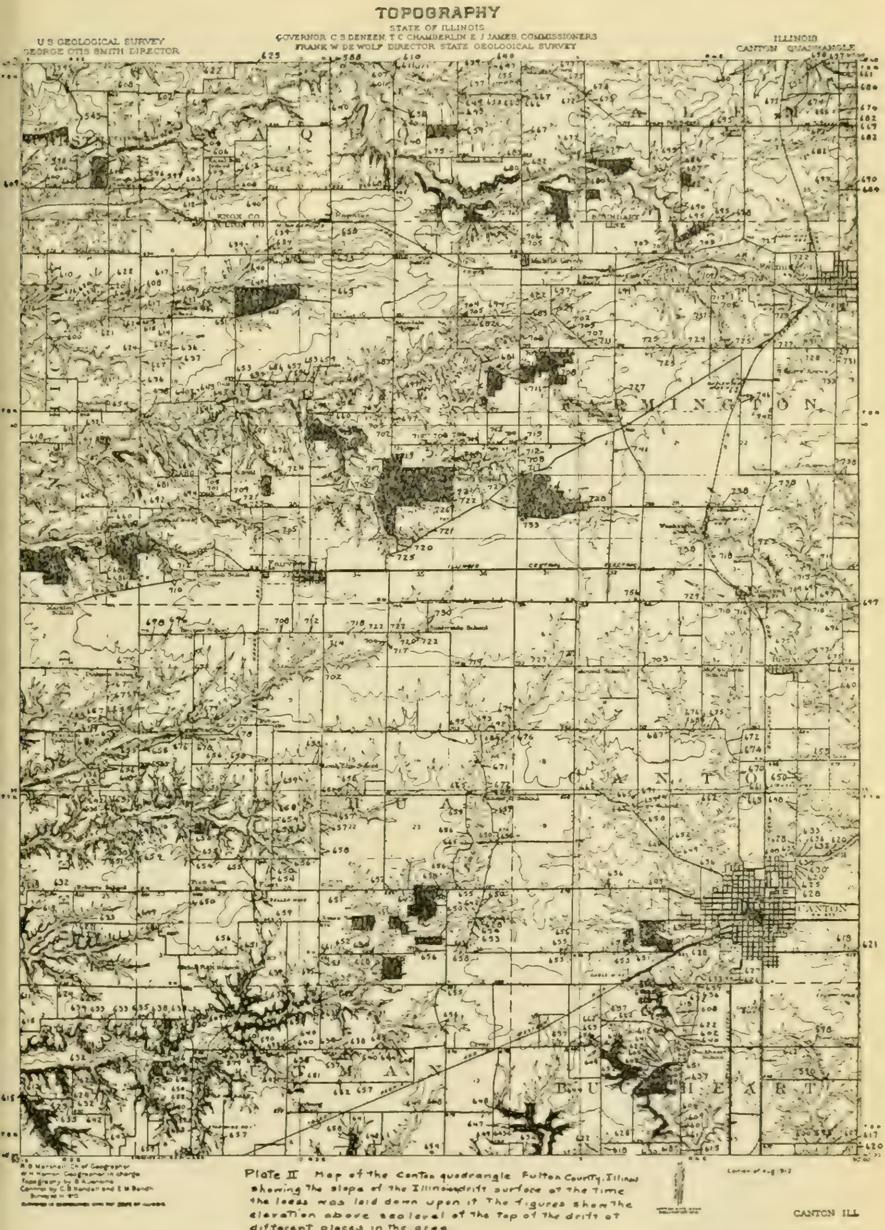

Plate II. Map of the Canton quadrangle, Fulton county, Illinois, showing the slopes of the Illinoian drift surface at the time the loess was laid down upon it. The figures show the elevation above sea level at the top of the drift at different places in the area.

From the detailed study of these and other areas it seems certain that the development of erosion slopes on the surface of the Illinoian drift previous to the deposition of the loess was several times that at present attained on the surface of the Early Wisconsin drift, indicating a correspondingly longer interval for its accomplishment than has elapsed since the withdrawal of the Wisconsin ice sheet.

It might be suggested that the surface of the Illinoian till, beneath the loess, reproduced the topography of the pre-Illinoian surface as a result of the present streams following pre-Illinoian channels that were not completely filled by the Illinoian till. Some of the larger streams in the Canton quadrangle are following pre-Illinoian channels, but only in a part of their courses, and many of the smaller streams have no place found buried channels. However, the slopes of the Illinoian till, beneath the loess, bordering the portions of the stream valleys, where they do not follow pre-Illinoian channels, are just as gradual as in the places where they do. The thickness of the Illinoian till in this region averages about 24 feet, which depth is sufficient to entirely obliterate all of the smaller pre-Illinoian valleys and many of the larger ones also, as the field study shows it has done. Hence the generally gradual slopes of the surface of the till, beneath the loess, bordering the smaller as well as the larger streams, could have been developed for the most part only by stream erosion on the surface of the Illinoian till, before the overlying loess was laid down.

TIME OF THE MAIN LOESS DEPOSITION

In the Mississippi Valley and elsewhere dust is at present being carried and deposited by the winds, and doubtless under favorable conditions of gathering and lodgment, the winds have carried and deposited such materials throughout past geological periods. It seems certain, however, that peculiar conditions unusually favorable for loess deposition, prevailed over the Mississippi valley during very late Iowan and early Peorian stages of the Pleistocene. This is shown, (1) by the intimate relations of the loess to the border of the Iowan drift plain above described, and (2) by the very slight development of loess on the surface by the Iowan and Wisconsin drift sheets compared with its much greater thickness over the older Kansan and Illinoian till.

That the most important loess deposition did not take place after the Iowan period of glaciation is shown by the absence of anything like such thickness of loess over the Iowan

Figure 9. Bluff of loess along the Mississippi River in Calhoun county, Illinois.

and Wisconsin drift sheets as is present over the surface of the older Illinoian and Kansan till. The maximum loess deposition did not occur until a long time after the Illinoian till was deposited as shown by the fact that (1) before the loess was deposited sufficient time elapsed for the development, on the surface of the Illinoian till, of erosion slopes and relief quite similar to those of the present surface; and (2) the interval between the deposition of the Illinoian till and of the overlying loess in Illinois was sufficiently long for the development in many places upon the surface of the Illinoian drift of the Sangamon soil horizon and beds of peat, and in others of an oxidized and weathered zone, and in still others of a zone of concentrated pebbles on the slopes by the removal of the finer constituents of the till, such as are found above the Illinoian till and below the loess in many places in Sangamon, Fulton, Menard, Champaign and other counties in Illinois.

Some loess-like material was doubtless deposited by the winds during each of the interglacial stages, for thin deposits of such character are known between the Kansan and the Illinoian and the Kansan and the Iowan drift sheets at numbers of places in the Mississippi Valley. However, the thickness of the loess between the Kansan and Illinoian till or between the Kansan and the Iowan is not nearly so great as that over the surface of the Kansan and the Illinoian till sheets. The pre-Iowan loess appears to have been limited in its distribution, compared with the present loess deposits, as is indicated by the following facts: (1) The loess is thin, only one to three feet, and of relatively rare occurrence between the Illinoian and the Kansan or between the Kansan and the Iowan drift sheets, while a thickness of several feet is common between the Illinoian and the Wisconsin till. (2) Masses of typical fossiliferous loess, in size up to 15 feet long and 4 feet thick, are often found incorporated in the Wisconsin till, but they are rarely or never found in the till of earlier age, in which masses of sand of corresponding size are not uncommon.

The relations of the loess to the drift varies with the valley slopes. In many places where the banks bordering the valleys of the larger streams are steep, the loess breaks off abruptly near the top at the uppermost exposed level of the till. In many other places where the bordering slopes are gentle and are favorably situated with respect to areas of flood plain and the direction of prevailing winds, a mantle of normal loess covers the slope to a thickness of from two or three to six or eight feet, often extending down almost or entirely to the level of the flood plain.

In the places where the loess terminates abruptly near the tops of the hills, at the uppermost level of the till, the banks are usually precipitous, and the streams have undercut their banks and thus widened their valleys since the time of major deposition of the loess. In this process the loess that was deposited in the earlier slopes has been removed as the work of valley widening by side cutting of the streams was accomplished. At these places the undercutting has taken place so recently that the banks are still steep and no appreciable amount of loess in excess of what has been eroded, has since been deposited upon them.

In some places where the loess continues down the slopes for a considerable distance below the upper level of the drift, the slopes are usually gentle, showing that undercutting has not there been in progress for a long time.

The presence of the loess over the slopes below the upper level of the drift may be accounted for in two possible ways: (1) It may be assumed to have been brought down from higher levels by slumping and sheet wash; and (2) It may have been carried up by winds from flood plain or other exposed areas and deposited on the slopes where it is now found. By the first assumption practically all the loess on such slopes would be of secondary origin, while by the second this loess would be largely in its original position.

The first assumption is open to the following objections:

1. Although landslides and slumping were doubtless important factors in the development of the gentle slopes, after undercutting had ceased, yet these processes would not result in the development over the surface of a mantle of fine homogeneous loess material, unmixed with till, after the gentle slope had been developed. 2. The effective action of sheet wash on slopes of rather uniform gradient tends to increase with the distance down slope from the top, so that any material transported for a distance near the top would tend to be carried to the foot and not deposited on the middle or lower part of the slope. 3. The thickness of the loess at the top of the hill, in places where the loess continues down the slope to the flood plain, is as great as it is in the places where it does not extend below the highest level of the drift. An immense quantity of material would be required to cover a slope ⅛ to ¼ mile in length to a depth of three to six feet, yet in not one of such places observed was there any diminution in the thickness or amount of the loess at the tops of the hills, showing conclusively that the loess on the slopes could not have been derived from the loess at the top of the hill.

Supporting the view that the loess which mantles the slopes below the highest level of the drift is an original deposit, is the general relation of such loess covered slopes to areas of flood plain and to the direction of prevailing winds.

Bordering the east bank of Spoon river, in Secs. 19 and 20, T. 9 N., R. 3 E., and Secs 24 and 25, T. 9 N., R. 2 E., and farther south in Secs. 10, 15, and 22, T. 8 N., R. 2 E., the till is entirely concealed down to the level of the flood plain by a covering of wind blown material, in some places loess and in others sand. The only evident source of the sand in this region is the adjacent flood plain of Spoon river to the westward, and this sandy alluvium would furnish a ready supply both of the sand and the finer loess material. Observations show that both sand and loess are at present being deposited on the slopes on the east side of the valley by the winds which gather the most of the material from the surface of the adjacent flood plain.

Relations similar to those in the vicinity of Spoon river generally exist between the thicker sand and loess deposits, not only on the bluffs, but also on the more gentle slopes bordering the windward side of the valleys and the areas of flood plains along the Sangamon and Illinois, and the other rivers, as well as many of the smaller streams, in Iowa and Illinois.

Some of the fine material gathered from the flood plain of the river may be carried by the wind for several miles, and this material, together with the dust swept by the winds from exposed portions of the intervening uplands, may be lodged on the bluffs and opposing slopes along smaller streams at a distance from the river and thus supplement the local supply.

The general relations of the loess covered slopes to the direction of the prevailing winds and the possible source of supply of the material together with the lack of any trace of removal or diminution in the quantity of the loess material at the tops of the hills in such places, make it practically certain that the loess occurring on the slopes below the uppermost level of the drift has been mainly deposited by winds since the present, gentle gradient of the slopes was developed, and that it is largely in its original position.

CLIMATAL IMPLICATIONS OF THE LOESS

Wind deposits are characteristic of arid climates, hence some geologists have assumed that arid conditions must have prevailed in the upper Mississippi Valley during the time of maximum loess deposition. Leverett[1] thinks that, since loess occurs in a few places between the Kansan and Illinoian drift sheets as well as more generally above the Illinoian and below the Wisconsin till, there must have been two periods of aridity in this region during Pleistocene time.

In his recent paper on the "Solar Hypothesis of Climatic Changes," Huntington[2] has assumed that arid conditions prevailed in the loess area of the Mississippi Valley during each of the stages of glaciation.

However, the following facts make it very improbable that anything like desert or even semi-arid conditions could have accompanied the deposition of the loess:

1. The regularity, or very gradual change, in the thickness of the loess over the uplands. Wind deposits in arid regions are notoriously dune-like and irregular. The level, loess covered prairies of the Illinoian drift plain present none of the irregular features characteristic of wind deposits in arid regions where a dense cover of vegetation did not control the permanent lodgment of the material.

2. The presence throughout the thicker loess deposits of shells of species of land snails that live at present on woodland hills in the same regions, indicates that similar conditions of habitat had existed throughout the time of accumulation of the loess deposits.

3. The absence of glacio-fluvial or other water laid deposits associated with the Iowan drift is also evidence opposed to an arid or semi-arid climate during that time, for under arid conditions the rains would be concentrated during a short season of the year, making the streams more effective in the transportation and deposition of coarse debris.

4. The uniformly fine grain of the deposit, which was derived from sources rich in coarser sand material, also precludes the possibility of arid conditions in which the winds had any greater efficiency than at present. The texture of the main portion of the loess deposits is as fine as that of the uppermost part which was presumably deposited under present climatal conditions in more recent time, and in any exposure there is generally no line or zone in which any change in the texture of the materials of the deposit can be detected.

In the loess deposits bordering the Embarrass and Wabash rivers in Crawford and Lawrence counties, Illinois, a bed of

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1. Frank Leverett: Weathering and Erosion as Time Measures. Am. Jour. of Science, Vol. XXVII, May, 1909, p. 361.
2. Ellsworth Huntington: The Solar Hypothesis of Climatic Changes. Bul. Geol. of Am., vol. XXV, No. 4, 1914, p. 577.

typical, yellowish-gray, fossiliferous loess, presumably of the Iowan age, in places rests directly upon the Illinoian drift, and is overlain by 1 to 5 feet of brown, homogeneous silt, the texture of which is similar to that of the lower loess. This brown loess-like clay, which in some places overlies the typical fossiliferous loess, mantles the surface over all of this region, and is thought to indicate a less rapid rate of accumulation of the upper loess, the deposition of this bed being so slow as to permit the complete oxidation of the material while it was being laid down, while the lower oxidized Iowan loess is thought to have accumulated so rapidly that the material did not become so thoroughly oxidized before it was buried. The texture of the material is similar throughout and does not indicate any difference in the power of the winds during the time both phases of loess were deposited.

Evidence of the lack of conspicuous flooded conditions of the streams attending the melting of the Iowan ice sheet, is clearly seen in the lack of association with this drift sheet of outwash deposits, gravel trains, eskers, and other glacio-fluvial features, associated as compared with the abundance and extent of such water sorted deposits in association with the Wisconsin till, or with the earlier Kansan and Illinoian drift sheets. This absence is doubtless due to the very slow rate of melting of the Iowan glacier, which slow rate of melting probably resulted from the prevalence of a somewhat unusually low temperature in the region during the melting of the Iowan ice sheet, and was not due to the existence of arid conditions during this time.

The loess deposits demand a climate so nearly like that of the present that the hills and uplands were covered with vegetation practically as today; that the winds were no more efficient in gathering or transporting materials than at present; that the land snails could live on the same forest covered hills which they now inhabit. These facts, together with the general lack of glacio-fluvial deposits associated with the Iowan drift are not consistent with arid conditions. It seems to the writer they can be better explained by assuming a slightly lower temperature during the melting of the Iowan ice sheet than attended the melting of the other ice sheets of the Pleistocene period, and continuation of this low temperature for a considerable time after the withdrawal of Iowa glacier, such as would retard for a time the establishment of vegetation upon the Iowan drift surface, and also delay the renewal of vegetation over the mud flats of river flood plains after they were overflowed by the streams.

Papers on Botany

A COMPARISON OF CERTAIN ROCKY MOUNTAIN GRASSLANDS WITH THE PRAIRIE OF ILLINOIS

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Grasslands occur at varying altitudes in mountain regions and are almost as widely distributed as the peaks and ranges themselves. Alpine and sub-alpine meadows are perhaps best known, but in them the preponderance of other herbaceous and low woody plants over the grasses is such that the fitness of the term grassland may well be questioned. At somewhat lower altitudes, particularly in the zone immediately below the sub-alpine and commonly known as the "montane," are found treeless areas that better deserve the title of grasslands. At times the transition from the forest is a gradual one, through areas of savanna in which trees are scattered at rather wide intervals over grass-grown fields. Such grasslands and savannas are a well marked feature of the eastern slopes of the Rocky Mountains in Colorado, and are also found in other neighboring states. From their open park-like planting they are popularly designated "parks." One of the best known is Estes Park, some 60 miles northwest of Denver, included within the limits of the recently created Rocky Mountain National Park.

It was the writer's privilege during the summer of 1914 to visit this Park with a class of students in field ecology and also to study for some weeks a smaller mountain grassland, known as Boulder Park, from South Boulder Creek, a small stream traversing the park from west to east. Boulder Park is 47 miles northwest from Denver upon the Moffatt Railroad, has an altitude of 8880 feet, is two and a half miles long, nearly a mile wide, and contains the little village of Tolland. On account of the richness and variety of its vegetation it was recently chosen by the University of Colorado as the site of its Summer Mountain Laboratory.

The grassland here occupies the floor of a mountain valley broadened by glacial action and partially filled with the gravels of terminal and lateral moraines. These gravels have been worked over so as to give the valley a comparatively level floor upon which South Boulder Creek meanders in broad curves, the channel often widening into shallow ponds on account of the low gradient assisted by the work of beavers. Two other shallow ponds or small lakes are drained into the creek. The stream has intrenched itself but little and the general appearance of the valley floor is not unlike that of the lake plain which succeeded the ice sheet in the Chicago region and is at present partly occupied by edaphic prairie. It therefore seems that it would be interesting to compare the conditions which have produced grasslands in these two areas, situated in rather widely removed regions and differing in so many respects. It may be possible that such a comparison may so stimulate inquiry that further research along this line may contribute something to the general problem as to the factors that are efficient in producing this type of vegetation. A full analysis of the composition of the vegetation is not possible nor is it either desirable or necessary, for it has already been rather completely done by Ramaley[1], Robbins[2], and others connected with the Colorado Mountain Laboratory.

CLIMATIC CONDITIONS

As already indicated the prairies of Illinois and the mountain grasslands of Colorado now under consideration, differ rather more than 8000 feet in altitude, and this brings a corresponding difference in temperature. The mean summer temperature of Boulder Park is about 15 degrees F. lower than that of the Chicago Region, only about six weeks of midsummer are usually free from frosts and a drop in temperature below the freezing point has been known to occur during almost every week of the year. There is almost no growth before June first, and very little after the end of August, thus making a short vegetative season that almost entirely eliminates annuals from the mountain habitat. Winter temperatures also differ somewhat, but probably not enough to materially affect vegetation, at least it may be said that this mountain park is no colder than many prairie regions, such as those of the Dakotas.

In humidity the two regions are probably closely comparable, although no accurate data are available from Boulder Park, where, in spite of the light showers that are an almost daily occurrence during a considerable portion of the summer, the mountain air is quite as dry as that of Illinois during the summer months. The amount of precipitation in the two localities is of the same order of magnitude, Illinois, (about Chicago) averaging a little over 30 inches and Boulder Park a little less than that amount, per annum. Curiously enough snow never accumulates to any great depths nor does it usually remain long in this valley, probably on account of the long slopes which lead directly down to it from the Continental Divide, here some 2500 feet above it, but less than ten miles distant.

Both localities are exposed to high winds, but the mountain habitat particularly so. During the colder months of the year in particular do westerly winds of high velocity and great desiccating power sweep down from the Continental Divide.

SOIL CONDITIONS

The soil conditions are very diverse. The rich agriculture of Illinois is associated with a prairie soil of almost exhaustless fertility. It is a dark, heavy loam or silt of rather fine texture, possessing, as has been shown by Harvey[3], a large water holding capacity as indicated by a high wilting coefficient. On the contrary, the soil of Boulder Park is lacking in fertility and coarse in texture, consisting of glacial gravels with a very small percentage of humus. No determination of its water holding capacity nor of its wilting coefficient have been made, but they are known to be low, since investigations of actual soil moisture conditions by Ramaley[4] show, during July, from 1.5 to 5.5 per cent of moisture in the drier portions, and only 11 per cent of moisture in the soil of the mesophytic meadow. In and about the shallow lakes there are small accumulations of peat and in portions of the sedge-moor the accumulation of humus has been rather considerable, so that in spots the soil becomes comparable in its organic content with that of corresponding areas in Illinois.

It seems certain that during the summer season the soil of this mountain habitat, except where it is at or near the water table, is deficient in soil moisture and this deficiency is reflected in the xerophytic aspect of its vegetation. It is interesting to note in this connection that Harvey[2] has found that the soil moisture in the Chicago prairie falls below the wilting coefficient at midsummer.

Summarizing the comparison of climate and soil factors in the two grasslands it will be seen that they differ widely in respect to altitude, length of growing season and in soil fertility and texture, but agree in possessing conditions of relatively low atmospheric humidity, in being exposed to high winds and in having a deficiency in the supply of soil moisture at least during the weeks of midsummer. Further the precipitation in the two habitats is practically the same in amount, although a closer study would probably show that it differs considerably in its distribution in relation to the growing season.

Both habitats have been subject to fires and it seems possible that fire may be a factor affecting to some extent at least the development and maintenance of grassland conditions. The arguments for its effectiveness in Illinois need not be discussed here and it may only be said that in the Rocky Mountains near the valley which was the site of these observations, where there had been repeated fires, the development of tree seedlings, seemed to be a slow and difficult matter.

THE PLANT SUCCESSIONS

In comparing the character and order of the development of the vegetation of the two grasslands the writer will limit himself to that portion of the Illinois prairie with which he is most familiar, that is, to its occurrence in the Chicago region and will also omit all but the necessary facts regarding this vegetation since they are already available in the reports of Cowles[5], Harvey and others. It will be necessary, however, to give rather more details regarding the Colorado mountain grasslands.

In both there is a well marked hydrarch succession of associations proceeding, in the Chicago region, from filling of the shallow lakes which followed the recession of the glacial Lake Chicago and which still persist in the form of larger and smaller bodies of water of which Calumet and Wolf lakes are examples. Very similar shallow lakes are found in Boulder Park as exemplified by Park Lake. The culmination of these successions is, in both regions, a rather mesophytic grassland that may very conveniently be designated prairie-meadow to distinguish it from the other associations of the series. Our present knowledge seems to point to this as the only manner of origin of the prairies of the Chicago region and as the usual course of development of most of the grasslands of Illinois, but in the Colorado mountain parks there is also a xerarch succession leading from the bare glacial gravels in a well marked series of associations slowly culminating in the same or a similar more mesophytic prairie-meadow.

THE HYDRARCH SUCCESSION

In the mountain parks of Colorado small shallow lakes are not uncommon, some being due to "kettle hole" origin at the time of the recession of the glaciers. Two of these, known as Park and East lakes, are found in Boulder Park and having been rather carefully studied the succession, may be taken as representative of that of this class of mountain lakes. The soil at the bottom and shores of the lake consists of the original glacial gravels with a very small amount of alluvium carried in by tributary streams, and a larger or smaller amount of peaty vegetation. The waters are nearly stagnant on account of the small amount of run-off from surrounding areas. The larger of these lakes is only about 3 to 4 feet deep, and the other but little deeper, the conditions being similar to such shallow lakes of the Chicago area as Wolf and Calumet. It would therefore be expected that the same associations would be represented in the two regions especially as no vegetation shows a wider distribution or greater uniformity than aquatic and sub-aquatic associations, and in fact the same type of succession is actually seen but with several notable differences.

The algal association in the mountain lakes instead of being abundant and varied as in Illinois, seems to be made up of a comparatively small amount of two species of *Spirogyra,* some *Chaetophora* and *Drapernaldia* and a few blue-green algae of small size. It seems safe to say that there is not more than 20 per cent of the mass or number of species of algae found as in similar shallow water in Illinois. The other submerged aquatic community may be termed the Myriophyllum-Batrachium association, from the two species *Myriophyllum spicatum* and *Batrachium trichophyllum,* its only members. The latter is the more abundant, but the mass of the two is small compared with the submerged aquatics of more eastern waters.

Separated from the associations already mentioned and occupying the shallow water near the shores is the main aquatic community, a pondweed association, characterized by plants with ribbon-like submerged and floating leaves. Its dominant member is a bur-reed, *Sparganium angustifolium,* whose leaves float on or near the surface, and *Potamogeton lonchitis* and *P. foliosus.* This paucity of forms contrasts with the conditions in Illinois where at least twice as many species and double the mass of vegetation are to be found in the corresponding habitat. The mountain lakes are also deficient in the entire absence of any association corresponding to the water lily or cat-tail associations, but the submerged and floating leaves of the pond-weed association are followed at once by the emergent sedges. Perhaps nowhere do the two regions resemble each other more closely than in this stage of the succession known as the sedge swamp, fen, or sedgemoor. It is true that many of the species are different but the same genera are present, and, what is more important, the ecological types are the same and the association occupies the same place in the succession.

In the Colorado parks this is often one of the most extensive associations in its extent and apparently is of rather prolonged duration. Several undetermined mosses are rather abundant upon the soil, but the initial and most abundant seed plant is *Carex utriculata,* soon mixed with *C. variabilis, C. lanuginosa, Eleocharis tenuis,* and such herbs as *Caltha rotundifolia, Sedum rodanthum, Montia chamissonis* and *Spiranthes stricta.* As soil formation advances and the drainage gradually develops, bringing the soil surface well above the ordinary water table, the change is marked by the invasion of *Carex festiva,* and many of the grasses of the succeeding grassland. It is, however, a noticeable feature of the grassland that many of the pioneers of the sedgeswamp persist in the meadow, a condition not uncommon also in the low prairie of Illinois.

Following the sedges is the main grassland community, termed the meadow association in the mountains, but corresponding directly with the prairie grassland of Illinois. In aspect the two agree closely, the bulk of vegetation being rather coarse grasses mingled with many herbaceous plants of other habits of growth. In both the other herbs outnumber the grasses in species, the mountain grassland abounding in species of *Eriogonum, Cerastium, Thalictrum, Potentilla, Geum, Epilobium, Gentiana, Pentstemon, Galium, Astragalus, Carduus, Senecio* and *Erigeron.* In many parts of the grasslands the limits of this meadow association may be determined by the distribution of *Erigeron macranthus,* a species that seems to be a certain indicator of the degree of mesophytism characteristic of this meadow. From the evidence at present available it is impossible to decide whether such a meadow is the true climax of these mountain parks, but it is certain that it persists for long periods and occupies the most mesophytic habitats outside the forests. In it the soil has the best development of humus and possesses the best water supply and in it is seen the greatest luxuriance of plant life, including a considerable number of species from the associations immediately above and below it. From the sedge-moor come *Carex festiva* and *C. variabilis, Calamagrostis canadensis, Deschampsia flexuosa, Koeleria cristata and Beckmannia erucaeformis,* while among the more mesophytic of the dry-grass species which intrude, are *Stipa comata, Festuca pseudovina* and several of the more mesophytic species of *Muhlenbergia and Agropyron.* Among the more abundant grasses are several species of *Poa, Agropyron, Agrostis, Deschampsia, Phleum* and *Bromus,* the last mentioned genus being particularly abundant wherever there is a contact between the forest and grassland.

THE XERARCH SUCCESSION

The porous condition of the glacial gravels, which form the greater portion of the soils of Boulder Park and similar montane areas, provide such excellent natural drainage that with the recession of the mountain glaciers large areas of these gravels must have been left without vegetation and with surface but little more inviting to plants than the bare rock. At present these gravels are seen upon the mountain slopes, the ridges representing lateral and medial moraines and in the irregularly placed terminal moraines. More level areas probably represent the gravel bars of glacial streams. Upon the dry suface of these soils lichens appear to have played a comparatively small part in the establishment of vegetation, probably on account of the instability of the surface particles during high winds. Still crustose and foliose lichens are fairly abundant upon the larger boulders. The most important pioneer plant appears to be *Selaginella densa* forming mats over and between the coarse soil particles. It is closely followed by the succulent *Sedum stenopetalum* and several xerophytic grasses growing as crevice plants. The mat forming habits of the *Selaginella* prepares the soil for the other pioneers, among which *Antennaria parvifolia, Arenaria Fendleri, Chrysopsis villosa, Orthocarpus luteus, Carex stenophylla* and *Commandra pallida* are conspicuous. The constant presence and predominance of the first mentioned xerophyte would make it appropriate to term this pioneer vegetation the "Selaginella association." It is characterized by low growing perennial plants, a large percentage of bare ground and very slow advance towards a less xerophytic condition. This slow advance is largely due to the low water content of the soil, due to its coarse texture and to the extreme slowness of the humus accumulation. High winds dry the dead vegetation, break it into fragments and carrying it off, leave almost nothing to form humus, while the little that may be formed is still liable to be removed by the same agency in the form of dust. The finer soil particles, resulting from the disintegration of the gravel, are aften lost in the same manner. The mat forming tendency most evident in the *Selaginella* and the habits of vegetative reproduction in such plants as the *Carex* and *Commandra* finally increase the amount of vegetation and make the entrance of new species an easier matter.

The succeeding community may be called the Carex-Artemisia association from the comparative abundance of *Carex stenophylla, C. filifolia, Artemisia frigida* and *A. canadensis.* Grasses also begin to be rather conspicuous, being represented by species of *Festuca, Muhlenbergia* and *Koeleria.* The mat-forming habits of several of these grasses is of the greatest importance because only within such mats does the formation of humus occur, and with it the advance of the association. Even in this association not more than one-half the surface is actually covered by the vegetation. About this time the invasion of other species in small communities giving a patchy character to the vegetation becomes conspicuous. Such aggregations are found of all species, but among the more conspicuous may be mentioned those of *Antennaria parvifolia, Campanula rotundifolia, Potentilla* spp., *Aragallus Lambertii, A. Richardsonii,* and *Achillea millifolium.*

The succeeding stage is well developed and is perhaps the most usual vegetation of the montane parks. It is characterized by the greater development of grasses in comparison with other herbaceous species and has been designated by Ramaley, who has studied it most extensively, the "dry grassland." From a study of the composition of a large number of permanent quadrats Ramaley[6] finds that there is still much bare ground, amounting to about 25 per cent of the whole area during the month of July. The same investigator reporting upon the composition of the vegetation finds 30 per cent of it composed of various species of grasses, species of *Muhlenbergia,* making up 8.18 per cent, and of *Festuca* 7.78 per cent. *Carex* spp. amount to 11.25 per cent and *Aragallus* spp. to 9.68 per cent, while *Selaginella densa* still covers more than 5 per cent of the whole area. Among the more common species are *Agropyron violacea, Festuca octoflora, F. pseudovina, Koeleria cristata, Poa* spp., *Muhlenbergia gracilis, M. Richardsonis, Stipa comata, Carex filifolia, Potentilla Hippiana, P. gracilis, Aragallus Lambertii, A. Richardsonii, Artemisia* spp. and *Pentstemon procerus.* Other species are rather numerous and some become locally abundant while it is to be noted that all the species of the pioneer associations persist. There can be no doubt that this dry grassland association in its various modifications is a comparatively permanent vegetation and it is even possible that it is the climax for the more exposed situations, altho a rather careful examination leads to the conclusion that it is gradually advancing in mesophytism largely through the mat and tuft habits of many of its grasses. This is accompanied by a slow addition of humus to the soil, improving its water-holding capacity, and this in turn reacting to cause a closer stand of vegetation. This transformation seems gradually to advance this succession to a more mesophytic association differing from that described as the climax of the hydrarch succession principally in the smaller amount of such species as *Carex festiva* and other secondary species of rather decidedly hydro-mesophytic character. Most of the grass species of the dry grassland association are still to be found, but the more xerophytic in decreasing abundance. The quantity of *Poa Muhlenbergia* and *Stipa* has increased and such forms as *Deschampsia, Agropyron, Danthonia, Poa* and *Avena* have come in. The grasses now show a greater predominance over other herbaceous plants although several new ones appear among the latter, the most conspicuous being *Erigeron macranthus* that seems to be a rather constant indicator of mesophytism. As previously noted this prairie-meadow association has a great variety of species, many showing peculiar local abundance, but unfortunately neither the extent of our investigations nor the space at our disposal permits their discussion in this paper. No more noticeable evidence of advancing mesophytism can be given than the data of Ramaley that the bare ground in the prairie-meadow is not more than 10 per cent of the total area and that it is often entirely absent. The question of the possibility of a forest invasion of these grasslands seems quite as far from settlement as that of the relationship of grassland and forests in Illinois and can not be discussed at present further than to remark that while the Colorado mountain grasslands show much evidence of great permanency, indications are not lacking that they are areas of potential forests and show the invasion of trees at certain points.

SUMMARY

From the preceeding rather superficial observations the following agreements and differences may be noted as existing between these Rocky Mountain grasslands and the prairies of Illinois, as seen in the Chicago region:

Agreements

1. The two regions have very similar conditions of rainfall and humidity and in both there is a midsummer deficiency in soil moisture.

2. In both there is a well marked hydrarch succession passing from the aquatics through the sedge-moor in a closely comparable series of associations.

3. Both possess a climax prairie-meadow association in which herbaceous species other than grasses are fairly abundant.

Differences

1. The two regions differ much, as has been shown, in altitude, in temperature, in length of growing season and in character of soil.

2. The mountain region is distinguished by the greater paucity of aquatic species.

3. The mountain region exhibits a xerarch succession comparable to nothing found in Illinois.

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STUDIES IN PHYLLOSTICTA AND CERCOSPORA.

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During the years 1912 and 1913, while Dr. F. L. Stevens was dean of the College of Agriculture and Mechanic Arts in Porto Rico, he made extensive collections of parasitic fungi. When he came to the University of Illinois, he donated this collection to the University. In my studies I have made use of this material, working chiefly on the two genera Cercospora and Phyllosticta, both of which belong to the group of Imperfect Fungi.

The genus Cercospora of about 700 species, contains many important parasites, chiefly causing leaf-spotting. The spots are variable in size and color, often bordered by a narrow reddish or purple margin, with a sordid-white center due to the fungal hyphae which penetrate into the leaf. The spots are usually definite, though in some instances indefinite, or even lacking when the leaf is covered with a smoky brown mass. If conditions are such that growth is abundant, the spots become hoary, due to the large number of spores. The fruiting bodies are conidia which are borne on the ends of hyphae or conidiphores, which vary in number and size, may be simple or branched, and are brown in color. They are often abruptly bent at the point of spore production, and thus conidial scars are left. Conidiophores are usually fasciculate, and may arise singly or in numbers from the stomata of the leaf. As a rule, they vary in length and septation with age. The conidia are hyaline, several septate and they vary in size and shape. They are usually elongate, clavate or fusoid, straight and sometimes attenuate at the end farthest from the conidiophore. Each cell of a conidia is capable of germination, and very often when spores fall on a leaf, they produce germ-tubes which infest the host through the stomata. Very few cross inoculations have been made, and, little is really known concerning the limitations of the species. When the host plants are different, minor variations in size, color, septation, etc., of the conidia and conidiophores, or in the macroscopic appearances of the spots are generally employed in distinguishing species.

The genus Phyllosticta is very large, comprising nearly 1200 species, only a few of which have been determined by comparison or cultural studies. These forms produce leaf spots which may be circular, angular or indefinite. This genus differs from Phoma in that it inhabits only the leaves, while the latter may spread over the fruit, twigs or stems, also in that Phoma never produces a definite spot. The leaf blotch caused by Phyllosticta is due to a weakening or killing of the leaf-tissue by the mycelium, which spreads throughout the leaf. When conditions are favorable, the spots develop rapidly and the greater part of the leaf from the margin to the mid-rib may become involved. Sometimes the spots are brown, giving the appearance of sunburn, or again they may be of yellowish color, or sordid-white, or perhaps gray, with a reddish-purple margin which may be concentrically zonate. The center of the spot often falls out, and eventually, when affected to such an extent that they can no longer function, the leaves fall, thus weakening the vitality of the tree. Instead of being borne on conidiophores as in Cercospora, the conidia are produced in pycnidia. They are usually on the upper surface of the leaf, though sometimes below, and appear as tiny black specks when large enough to discern with the aid of a lens. They may occur singly or in clusters, and may be immersed, erumpent or superficial. When immersed a beak pierces the epidermis, thus facilitating the escape of conidia. The pycnidia are lenticular to globose, usually brown or black, opening by a pore or ostiole which is often dark-bordered. The conidia are hyaline, usually ovate to elliptical, though sometimes spherical, and they vary in length from 2 to 60 μ. The perfect stage of this fungus is known in but few cases.

It has been the custom when creating new species to designate as new those forms which have never been reported on the particular host or any genus of the same family, and which are distinct from any form on a related host. In working over some 50 different forms, I have found 15 which are distinctly new species. However, I am somewhat hesitant to describe these as Phyllostictas, rather than Phomas, since I believe there is no tenable distinction between these two genera. They are alike in conidia and pycnidia, and these parts seem to me to be the most characteristic. The general nature of the spots cannot serve as distinguishing features since they are both definite and indefinite on the leaves, nor does it seem justifiable to make the location of infection of a plant a basis for distinguishing species.

A METHOD OF PROPHESYING THE LIFE DURATION OF SEEDS

J. F. GROVES, UNIVERSITY OF CHICAGO

Since former explanations of the loss of vitality of seeds in storage conditions have proven incorrect, we have been led to surmise that a gradual coagulation of the proteins in the embryo may offer such an explanation. It has been shown by Chick and Martin[1] that proteins do not have a fixed temperature point for coagulation, but that coagulation may occur at any temperature provided the time of exposure be sufficiently great. Buglia[2] has applied the following time temperature formula to protein coagulation: $T=a-b \log Z$, in which $T=$ temperature cent., $Z=$minutes of exposure, and a and b constants. Lapeschkin[3] applied this formula to the coagulation of proteins in active plant cells and found a close agreement in theoretical and found values where time duration was short.

In this investigation constant temperatures were obtained by the use of the thermostat shown in figure 10. An external water bath contains a vessel of smaller dimensions which is connected with a water-cooled reflux condenser. Mixtures of ethyl and methyl alcohol and water used to provide desired temperatures and the seeds, in closed test-tubes, are suspended through closed perforations.

After quantities of seeds were exposed to a given temperature for various lengths of time, they were sterilized in an aqueous solution of silver nitrate and placed in sterile petri dishes for germination. Daily records were kept as in table I. Increased time of heating shows a delay in germination as well as a fall in germination percentage which is also true of seeds stored for a long time at room temperature.

Table II shows the life duration at various temperatures as found by experiment and the calculated life duration according to the formula. The constants a and b were found by the method of least squares from the found values of T and Z, and from these T was calculated for the various values of Z. The found values agree quite closely with a curve plotted for the theoretical values.

The temperature coefficient of life duration of wheat is found to be 7 or 8 for each 10 degrees change of temperature. Goodspeed[4] working with barley found a coefficient of life

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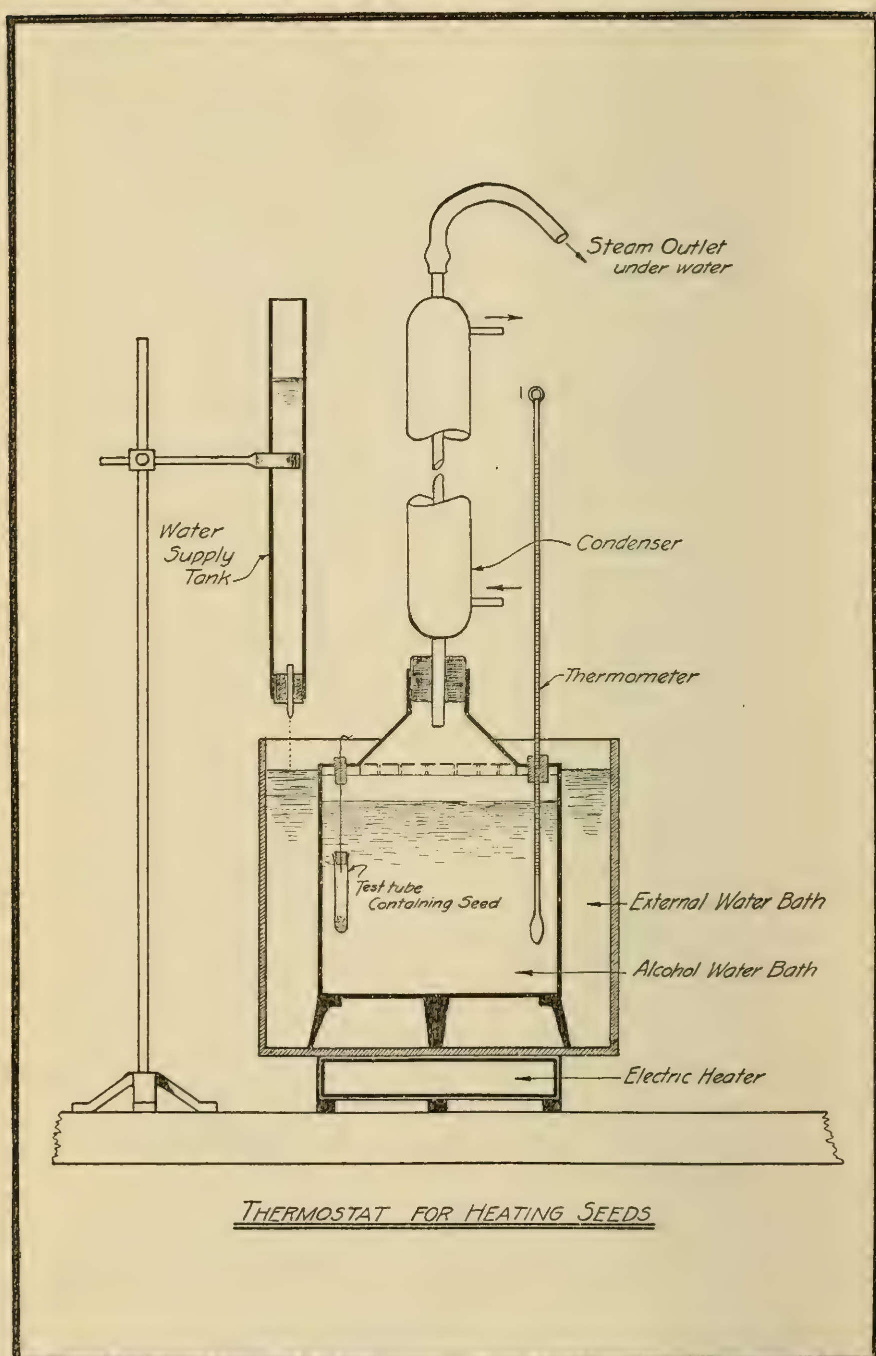
Steam Outlet
under water
Water
Supply
Tank
Condenser
Thermometer
Test tube
Containing Seed
External Water Bath
Alcohol Water Bath
Electric Heater
THERMOSTAT FOR HEATING SEEDS

Figure 10

duration of about 11, but since he did not control the water content, we are not justified in making a comparison. Loeb[5] working with sea urchin eggs found a coefficient of 500 to 1,000, while Moore[6] working with hydroids found a coefficient of about 1,000. The high water content in these cases probably materially affects the value. It should be noted that we are not dealing with a homogeneous system, but with a colloidal system and that it is not remarkable that the Van't Hoff temperature law for the rate of reaction does not apply.

Since here is a close agreement between the calculated and found values it seems probable that the time temperature formula for protein coagulation can be applied as a formula for the temperature-life duration for seeds. In order to establish the general application of this principle much more work is needed and several influencing factors are to be considered as here-to-fore outlined by Crocker and Groves[7]. The work shows possibilities of throwing light on the nature of the process of loss of vitality in seeds and of leading to a quantitative statement of the significance of various storage conditions, especially moisture content and temperature, upon the longevity of seeds.

This work was done under the direction of William Crocker, University of Chicago.

TABLE I

RECORD SHEET NO. 21, TURKISH RED WHEAT

Temp. 87.5. Moisture 12%, April 10, 1914.

Time in days	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Control	0	2	2	4	3	3	0	0	0	0	0	0	0	0	0	0	0	0
	92	92	92	93	95	95	98	98	98	98	98	98	98	98	98	98	98	98
7 min.			0	15	12	7	8	7	8	7	5	3	3	4	4	4	3	2
..			2	5	27	41	49	55	61	64	67	70	72	72	72	72	73	74
8 min.					4	8	8	7	8	7	5	3	1	5	1	1	1	0
					5	10	25	30	35	41	47	52	54	54	58	59	59	60
9 min.						2	4	4	5	4	5	4	5	2	3	6	5	4
						2	4	8	10	11	18	25	28	32	34	35	37	38
10 min. (Percent partially germinated										1	3	4	6	4	3	3	4	5
(Percent Germinated										0	0	0	0	4	5	9	11	11
11 min.												1	1	0	0	1	2	1
												1	1	2	4	4	4	5
12 min.													2	2	2	2	2	2
													0	0	0	2	2	2
13 min.																		
																0	0	0

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6. Archiv. Entiv. Mech. 29:145-287.
7. Proc. Ntl. Acad. of Sci., Vol. I, p. 152, 1915.

TABLE II.

GERMINATION RECORD TURKISH RED WHEAT

Theoretical temperatures calculated by formula: T=a-b log Z.

Notation: T=Temperature, Z=Time in minutes, a and b are constants.

Value found for a—98.88. Value found for b—11.78.

Trial No.	Duration in Minutes	Found Temperature	Calculated Temperature
A	7	89.2	88.9
B-C	8	87.7	88.2
D-E-F	9	87.5	87.6
G	10	87.5	87.1
H	15	84.4	85.0
I	18	84.4	84.1
J	45	78.9	79.4
K-L	50	79.1	78.9
M	50	78.5	78.9
N	120	75.8	74.4
O	315	71.3	69.5
P*	8 years	20	20.9

*Data from White's Experiment. Proc. Royal Soc. London, 81, 417, 1909.

PECULIAR EXAMPLES OF PLANT DISTRIBUTION A PROBLEM IN PHYTO-GEOGRAPHY

H. S. PEPOON, LAKE VIEW HIGH SCHOOL

ABSTRACT

Based upon the collection of 1800 species in the Chicago area, 1000 species in Fulton county, and 900 species in the driftless area of Jo Daviess county, the author cites numerous examples of peculiar or unique distribution of plant species, many of the examples being "extra limited" as far as the printed record presents the assigned localities.

He endeavors to group these examples under four main causative agencies that may be tabulated in the order of their increasingly greater numbers of representatives, as follows:

a. Aboriginal plantings.

b. Vestigial forms of glaciated times.

c. Extension outpost forms.

d. Survivals of destruction by human agency.

Some 50 species are named in the discussion and the author invites friendly criticism and further enumeration of examples.

THE GRASS FLORA OF ILLINOIS

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The grasses of the State have been listed several times in connection with various published floras of the State, but as far as I know only one paper has been devoted solely to this subject. This is a paper by I. A. Lapham of Milwaukee, who in 1857 listed and described 50 genera and 114 species of grasses, excluding those cultivated for grains. He also published a flora of the State in the same volume of the Transactions of the Illinois State Agricultural Society. Additions to this list were made from time to time by Dr. Brendel, M. S. Bebb, S. B. Mead and Dr. Vasey. The first extensive local flora was published by H. H. Babcock of the plants found around Chicago. He listed 58 species of grasses. H. N. Patterson of Oquawka published a flora of the State in 1876, in which he included 52 genera of grasses and 124 species. In 1878 W. C. Flagg compiled from these previous lists a flora of Illinois, having in addition some material collected by Dr. Burrill and others in the vicinity of the University. He included 55 genera and 139 species of grasses, which is probably the largest list of grasses of the State up to the present time. There have been a number of other local lists published. Some of them contain very few grasses. The most important of the local lists are Dr. Brendel's of Peoria, in 1887, including 70 species of grasses, a flora of Cook county by Higley and Raddin, including 85 species, and a flora of LaSalle county by Huett with 79 species. In undertaking to work over the grass flora of the State, the collections of the previously mentioned writers have been consulted as far as possible.

The University of Illinois has many specimens collected by Mead, Webb, Vasey, Hall and Patterson, beside the entire collections of Dr. Brendel of Peoria, Dr. Schneek of Mt. Carmel, and Dr. Welsch of Mascoutah. The later collections of V. H. Chase of Stark county, F. E. McDonald of Peoria, and Chas. Robertson of Carlinville, contained many interesting species. The Field Museum in Chicago contains Patterson's entire collections with many others collected by Wolf, Mead, Bebb and others. Babcock's herbarium is at Northwestern University and has been consulted, but the entire collections of Dr. Vasey have not been seen nor that of Prof. E. J. Hill of Chicago, who has made some new records for the State.

A careful study of this material succeeded in verifying 125 out of the 139 species mentioned in Flagg's list, which includes practically everything mentioned by other authors.

There are in all, 22 species reported from Illinois of which no authentic material has been seen. Some of these are reported in Gray's Manual and Brittain and Brown's Illustrated Flora as occurring in Illinois, but no Illinois specimens are found either in the Gray Herbarium, the New York Botanical Garden, nor the herbarium of the U. S. Department of Agriculture. Many of these were plainly wrong determinations, but others may yet be found when more material is examined.

Of the 125 species mentioned in Flagg's list there are 25 species introduced from Europe. My own list at present contains 187 species, of which 36 are introduced, making 62 species more than have been reported in a State list up to this time, or an increase of 50 per cent. It will perhaps be interesting to consider for a moment where these 62 new species have been obtained. As is well known, the majority of species in our Illinois flora belong to genera which are most abundant in warmer climates and of our 151 species native to Illinois, two-thirds belong to genera which are most abundant in the southeast and some are also found in Mexico. Nearly all of our species found in sandy or very dry soil have such an origin, and these, for the most part, are confined to such areas throughout the State. Apparently they have spread from one sand area to another, but of that we have no certain knowledge. Such are most species of the genera Sporobolus and Aristida, some Panicums, certain Eragrostis species, Triplasis purpurea, Cenchrus carolinianus and many others. Of the remaining third we have a large number which are found all over the eastern United States, such as Andropogon scoparius, Seersia oryzoides, Festuca octoflora and others. In the northern part of the State, particularly around the lakes, we have several species which are more abundant to the north of us, such as Phalaris arundinacea, Ammophila arenaria, Bromus Kalmii and others. We have very few typically western forms, probably our Bouteloua species are more so than any others in our grass flora.

Of these 62 species not included in the earlier lists 9 are species introduced from Europe. These include *Bromus incanus* and *tectorum,* the latter of which is spreading very rapidly in the State, *Lolium tementulum* or bearded darnel, *Hordeum nodosum, Panicum miliaceum,* the old world millet, *Arrhenatherum elatius* or tall oat grass, *Helochloa schoenoides* and *Sorghum halapense* or Johnson grass, which has been cultivated in the south and has been found in various localities in the state and as far north as Chicago. A few species have apparently come into Illinois from neighboring States, and the most remarkable fact is that most of them come from the west. Among these are *Agropyron tenerum* and *Smithii, Bromus pumpellianus, Sporobolus asperifolius* and *Hordeum Pammeli.* Another *Argropyron* species, *dasystachum,* has come in from the north, while the south has given us *Agrostus Elliotana, Muhlenbergia capillaris, Sporobolus clandestinus* and *Eragrostis Wiegeltiana.* Most of these have never been reported from the State. The majority of new species, however, has come from revision of material collected by the early botanists, a great deal of which had not previously been determined. The genus Panicum has made the greatest gain as to number of species, now including 34 instead of 9. These have all been published by Hitchcock and Chase in their revision of the genus. The genus Sporobolus gains 7 new species, Paspalum 4, Aristida 2, and Poa 2. Of the Poas one is the rare species *P. wolfii,* the type of which was collected in Illinois, the other native species, *P. Chapmaniana,* which resembles the introduced species, *P. annua,* so much that they are usually all labelled *annua* in the various collections examined. Dr. Brendel, Peoria, had noticed the difference, however, and his specimens of *Chapmaniana* were all unnamed with a note "A Poa with the habits of *annua* and the spikelets of *pratensis,*" which is a very good definition of the species.

There have been many species collected in adjoining States very near the boundary lines which may occur in Illinois now, but have never been collected. In fact, there are representative collections from very few counties in the State and from nearly half the counties there are no specimens at all. It seems quite probable, with further study of the material in existence and with new collections which may be made, that the number of grasses now occurring in Illinois, or that have occurred here, may be very materially increased.

A FLORIDA SMUT, USTILAGO SIEGLINGIAE, IN ILLINOIS

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While in Havana, Illinois, the latter part of last November, I collected a few grasses at a place locally known as Devil's Hole. It is a small area on which the sand dunes are so active that it cannot be used for cultivation. There grow here the xerophytic plants and bunch grass associations which are characteristic of typical blowouts. A point of peculiar interest regarding this region is that the animal life as well as the plant life is similar to that of the southwestern States[1].

In our study my classmate and I became interested in a grass which at first glance we thought was a dwarfed form belonging to the genus Sporobolus, but a careful examination of the spikelets gave indications that it was Triplasis purpurea (Walt.) Chapin. However comparison with herbarium specimens from the same county showed that although the less evident but more important characteristics were similar, the superficial but more apparent ones were not. Our conclusion was confirmed by the examination of a smut growing in the ovaries, the identity of which was determined by Dr. Wm. Trelease. It proved to be Ustilago sieglingiae[2] Ricker, which uses Triplasis purpurea as a host, but has been collected only from Punta Rassa, Florida[3]. Examination of such periodicals as "The Journal of Mycology," "Just's Botanischer Jahresbericht," and "Phytopathology," gave no evidence that it had been reported in any other region.

A careful comparison was made between the spores of the material found in Havana and those of the type material, a small amount of which Dr. J. J. Davis obtained from the herbarium of the department of plant pathology of the University of Wisconsin, and kindly sent to Dr. Wm. Trelease. They were similar in all respects, except size, the type spores seeming to be smaller. Exact measurements proved that the extremes in size are the same in both cases, the smallest being 3 μ by 4μ and the largest 4.5 μ by 6μ, but that the average size of the type spores (3.53 μ by 5.16 μ) is slightly smaller than the Havana material, (6.56 μ by 5.4 μ).

Apparently the specimens of Triplasis purpurea attacked by the smut are different from those which are not. They are only one-third as tall as the herbarium specimens, but are more freely branched; the internodes are so shortened that the sheathes overlap; the panicles are all partially or wholly

enclosed in the sheathes instead of the largest ones being long exserted; the spikelets are somewhat larger; the ovaries have developed into rather large ergot-like bodies about 4 mm. long and 1.5 mm. in diameter, and the glumes, lemmae, and paleae are membranous and paler in color, but the number, shape and arrangement of these flower parts are the same.

However, these differences are not all due to the action of the fungus. It will be remembered that the collection was made late in the fall. Enclosed and cleistogamous spikelets are characteristic of late specimens in the genus Triplasis, including Triplasis purpurea[4]. This would account for the lack of exserted panicles and probably for the difference in texture of the flower parts. But the abnormal development of the ovaries is entirely due to the fungus.

In order to understand the occurrence of Ustilago sieglingiae in Havana we must consider its geography. It is situated in a sand deposit in the midst of a broad glacial flood plain. Its geologic conditions are therefore local, so that the smut must have reached it by transportation through short distances from sand patch to sand patch. It is surprising then, that it has not been collected from some sand area intervening between Punta Rassa and Havana, two places in which the meteorological conditions are very different. If, as is possible, it attacks only the autumnal forms of its host, it has probably not been obtained from these other localities because collectors have searched for it earlier than it appears. We believe that it can be found in such regions when the conditions are the same as those under which our material grew. Next summer and fall, if I can secure more material, I shall continue this study in hopes of getting confirmation of the thought I have advanced, or of getting new light on the subject.

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Papers on Zoology

WHAT CALIFORNIA IS DOING FOR THE CONTROL OF INJURIOUS INSECTS

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California has been the pioneer in many matters pertaining to horticulture. The work as now carried on is under the direction of a horticulture commissioner, a skilled horticulturist and entomologist appointed by the Governor. He has a deputy commissioner and secretary to assist him. In practically all counties there is a county board of horticulture consisting of three members. To carry on the work more thoroughly the board divides the county into districts and appoints a local inspector for each district who has full authority to cause the inspection of any orchard, nursery, packing house, trees or plants. If any are found infested by injurious insects, the inspector must notify the owner and the owner is required to eradicate or destroy them within a certain specified time. If he fails to do this the county board does it at the expense of the county and attaches lien to the property.

The State has two aims in its work, to eradicate the injurious insects already in the State, and prevent all others from entering. To accomplish the first of these the State is trying by means of farm advisers, correspondence instruction, and monthly bulletins to spread the knowledge of the injurious insects and method of their control among the ranchers and growers. For the State must have their interest and co-operation to obtain the best results.

Artificial means of fighting insects by spraying and fumigation have proved so costly and insufficient that it is the work of the State to discover, introduce and establish new parasites to prey upon the injurious insects. It was in California that the natural parasites were first used to combat the insect enemies, and so thorough has been this work along all lines that there are today few serious pests for which there is not an effective enemy. Expert entomologists are kept in the field in California, in other states, and countries, who collect these parasites. They are forwarded to the State Insectary where they are supplied with the proper hosts and reared in sufficient numbers to be sent out into the sections of the State where the destructive insects upon which they prey are found.

As the most serious pests have been introduced species, it is important for the State to keep those from neighboring states and countries from entering. California has been a pioneer in affording a most complete system of protection to her main industry of agriculture, by means of quarantine, and it was first in California that we find the word quarantine as applied to strictly horticultural material. Express shipments are as vigilantly inspected as those of freight and steamer. In spite of the strict quarantine laws and the efficient service, there still exists an open door by which injurious insects may enter and that is through the mail. This is especially true since the establishment of the parcel post and this door can only be closed by action on the part of congress, whereby the present law requiring the immediate delivery of mail will be abolished and making it mandatory that all packages of fruit and nursery stock be sent to two or three designated post offices for inspection and if found free of injurious insects to be then forwarded to the purchasers. It is toward obtaining such a law that the government is now working.

THE LABIUM OF THE NYMPHS OF ZYGOPTERA

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Several forms of labia occur in the Zygoptera, differing mainly as regards shape of mentum, submentum and lateral arms. There are also variations in the number of setae possessed by the different parts.

The labium can be homologized throughout with that of other insects. Palpi, ligula, mentum and submentum are present.

The use of the labium for capturing prey has led to rather extensive muscular development within. Two pairs of mental muscles serve to operate the organ to open and close the lateral arm. Two pairs of submental muscles, together with a pair of oblique basal muscles, open and close, extend and retract the piece as a whole. The presence of a median unpaired chitinous "rod" or ligament aids in this last operation, and is of interest because it occurs only in the Order Odonata . Caudad it is attached to the dorsal, ental surface of the submentum not far behind the articulation of that portion with the head capsule. Cephalad it is fastened to the cuticle immediately behind the hypopharynx.

THE COMPARATIVE MORPHOLOGY OF SOME CARABID LARVAE

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Carabid larvae have been studied but little in America, and it is generally believed that they do not possess distinguishing characters. A morphological study, however, shows distinct structural differences. These differences are found in the comparative length, size, and shape of the segments of corresponding structures. The number and arrangement of the setae upon the various appendages and sclerites of the body show distinct differences among the different species of larvae. The antennae, mandibles, maxillae and labium are well supplied with distinctive characters. The front and clypeus also shows considerable variation in its comparative length and width, the nature of its cephalic margin, and the number and arrangement of the setae.

SOME ADAPTATIONS FOR RESPIRATION IN AQUATIC HEMIPTERA

ABSTRACT

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In Benacus griseus, the "giant water bug," or the "electric light bug," there is a pair of "strap-like appendages" projecting from under the wings, at the posterior end of the abdomen, in both male and female. Their morphology and function have not been exactly stated.

On soaking specimens in caustic potash, these appendages are found to be projections from and parts of the tergites of the 8th segment. Similar organs are present in Belostoma fluminea say (Zaitha), and very short ones in Notonecta. Both are the same, morphologically, as the ones in Benacus.

There is a large spiracle at the base not only of each projection, but also of a groove extending from the spiracle to the tip of the "strap-like" portion of the tergite. This groove is edged on both sides with a row of long, closely-set setae. Records of observations* as to methods of breathing in Zaitha

*Bueno, J. R. de la Torre: Life Histories of North American Water Bugs.
I. Life History of Belostoma fluminea Say. Can. Ent. 1906; v. 37, 1906, pp. 189-197
II. Life History of Ranatra quadridentata Stal. Can. Ent. v. 38, 1906, pp. 242-252.

and other aquatic hemiptera by Mr. J. R. de la Torre Bueno, lead one to feel confident that the organs described above, in Benacus, and Notonecta, as well, are respiratory in function.

(Paper illustrated by lantern slide, showing structures mentioned.)

A MORPHOLOGICAL STUDY OF THE HEAD AND MOUTH-PARTS OF THE BLOW-FLY

ABSTRACT

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In order to reach a correct interpretation of the head and mouth-parts of the highly specialized Muscidae it is necessary to study the more generalized Diptera. At present such a study is being made. So far I have been able to secure representatives of thirty-eight families out of sixty-one listed by Williston. As a result of the observations on the forms thus far studied, a number of interesting relationships with respect to the mouth-parts have been worked out. When all the observations which I propose to make have been recorded, I feel quite sure that a number of the different points in the interpretation of the mouth-parts of the higher Muscidae (Blow-fly) will be made clear.

PUPAE OF THE LEPIDOPTEROUS FAMILY SPHINGIDAE

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The pupae of the family in Sphingidae belong to the so-called obtect type of pupa in which the appendages are firmly soldered to each other and to the body.

They retain, however, one very primitive character, the presence of a portion of the first femur between the maxillae and the remaining portions of the first leg.

By far the most interesting thing about these pupae is the way in which they provide for the very long maxillae which are present in most of the sub-families. The body is strongly curved on the ventral surface, and the labrum is found on the dorsal surface of the head in many instances, thus allowing for considerable extra length. Others have a prominent convexity at the proximal end of the maxilla where it is curved away from the remainder of the appendages. In one sub-family to which our common tomato worm, *Protoparce sexta,* belongs, the extra length is taken up in a sort of loop at the proximal end of the maxillae. This loop is closely appressed to the surface of the body, or prominently arched and touching only at its tip, forming the "jug-handled" type of pupa belonging to the above-mentioned species.

CONSTITUTION AND BY-LAWS

Illinois Academy of Science

CONSTITUTION

ARTICLE I. NAME

This Society shall be known as THE ILLINOIS ACADEMY OF SCIENCE.

ARTICLE II. OBJECTS

The objects of the Academy shall be the promotion of scientific research, the diffusion of scientific knowledge and scientific spirit, and the unification of the scientific interests of the State.

ARTICLE III. MEMBERS

The membership of the Academy shall consist of *Active Members, Non-resident Members, Corresponding Members, Life Members and Honorary Members.*

Active Members shall be persons who are interested in scientific work and are residents of the State of Illinois. Each active member shall pay an initiation fee of one dollar and an annual assessment of one dollar.

Non-resident Members shall be persons who have been members of the Academy but have removed from the State. Their duties and privileges shall be the same as those of active members except that they may not hold office.

Corresponding Members shall be such persons actively engaged in scientific research as shall be chosen by the Academy, their duties and privileges to be the same as those of active members, except that they may not hold office and shall be free from all dues.

Life Members shall be active or non-resident members who have paid fees to the amount of twenty dollars. They shall be free from further annual dues.

Honorary Members shall be persons who have rendered distinguished service to science and who are not residents of the State of Illinois. The number shall not exceed twenty at one time. They shall be free from all dues.

For election to any class of membership the candidate's name must be proposed by two members, be approved by a majority of the committee on membership, and receive the assent of three-fourths of the members voting.

All workers in science present at the organization meeting who sign the constitution, upon payment of their initiation fee and their annual dues for 1908 become charter members.

Article IV. Officers

The officers of the Academy shall consist of a President, a Vice-President, a Chairman of each section that may be organized, a Secretary, and a Treasurer. These officers shall be chosen by ballot on recommendation of a nominating committee, at an annual meeting, and shall hold office for one year or until their successors qualify.

They shall perform the duties usually pertaining to their respective offices.

It shall be one of the duties of the President to prepare an address which shall be delivered before the Academy at the annual meeting at which his term of office expires.

The Secretary shall have charge of all the books, collections, and material property belonging to the Academy.

Article V. Council

The Council shall consist of the President, Vice-President, Chairman of each section, Secretary, Treasurer, and the president of the preceding year. To the Council shall be entrusted the management of the affairs of the Academy during the intervals between regular meetings.

Article VI. Standing Committees

The Standing Committees of the Academy shall be a Committee on Publication and a Committee on Membership.

The Committee on Publication shall consist of the President, the Secretary, and a third member chosen annually by the Academy.

The Committee on Membership shall consist of five members chosen annually by the Academy.

Article VII. Meetings

The regular meetings of the Academy shall be held at such time and place as the Council may designate. Special meetings may be called by the Council and shall be called upon written request of twenty members.

Article VIII. Publication

The regular publications of the Academy shall include the transactions of the Academy and such papers as are deemed suitable by the Committee on Publication.

All members shall receive gratis the current issues of the Academy.

Article IX. Affiliation

The Academy may enter into such relations of affiliation with other organizations of appropriate character as may be recommended by the Council and be ordered by a three-fourths vote of the members present at any regular meeting.

Article X. Amendments

This constitution may be amended by a three-fourths vote of the members present at an annual meeting, provided that notice of the desired change has been sent by the Secretary to all members at least twenty days before such meeting.

BY-LAWS

1. The following shall be the regular order of business:

    1. Call to order.
    2. Reports of officers.
    3. Reports of standing committees.
    4. Election of members.
    5. Reports of special committees.
    6. Appointment of special committees.
    7. Unfinished business.
    8. New business.
    9. Election of officers.
    10. Program.

    Adjournment.

II. No meeting of the Academy shall be held without thirty days' previous notice being sent by the Secretary to all members.

III. Fifteen members shall constitute a quorum of the Academy. A majority of the Council shall constitute a quorum of the Council.

IV. No bill against the Academy shall be paid without an order signed by the President and Secretary.

V. Members who shall allow their dues to remain unpaid for three years, having been annually notified of their arrearage by the Treasurer, shall have their names stricken from the roll.

VI. The Secretary shall have charge of the distribution, sale, and exchange of the published transactions of the Academy, under such restrictions as may be imposed by the Council.

VII. The presiding officer shall at each annual meeting appoint a committee of three who shall examine and report in writing upon the account of the Treasurer.

VIII. No paper shall be entitled to a place on the program unless the manuscript or an abstract of the same shall have been previously delivered to the Secretary.

IX. These by-laws may be suspended by a three-fourths vote of the members present at any regular meeting.

List of Members

(Revised May, 1915.)

HONORARY MEMBER

Trelease Wm., LL.D., University of Illinois, Urbana. (Botany).

CORRESPONDING MEMBERS

Abbott, J. F., A.M., Washington University, St. Louis, Mo. (Zoology).
Coulter, S. M., Ph.D., Lafayette, Ind. (Botany).
Eycleshymer, A. C., Ph.D., Physicians & Surgeons Medical College, Chicago. (Anatomy).
Lyon, E. P., Ph.D., University of Minnesota, Minneapolis. (Physiology.)
Turner, C. H., Sumner H. S., St. Louis, Mo. (Zoology).
Widmann, O., Ph.D., 5105 Morgan St., St. Louis, Mo. (Ornithology, Botany).

LIFE MEMBER

Latham, Vida A., M.D., D.D.S., 1644 Morse Ave., Chicago. (Microscopy).

ACTIVE MEMBERS

Abbott, Miss Frances D., A.B., 523 S. Glenwood Ave., Springfield. (Biology).
Abbott, Walter S., Bureau of Entomology, Washington, D. C. (Entomology).
Ackert, J. E., A.B., University of Washington, Seattle, Wash. (Zoology).
Adams, Howard W., Normal, Ill. (Chemistry).
Akeley, C. E., American Museum, New York, N. Y. (Taxidermy).
*Andrews, C. W., A.M., The John Crerar Library, Chicago, (Sci. Biblio.)
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Baker, Frank C., Chicago Academy of Sciences, Chicago. (Conchology).
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Barber, Fred D., State Normal University, Normal. (Physics).
Barger, Thos. M., University High School. Normal.
*Barnes, H. O., A.B., High School, Springfield. (Mathematics).
Barnes, R. M., LL.B., Lacon. (Zoology).
Barnes, William, M.D., Decatur. (Lepidoptera).
Barrett, J. T., Ph.D., Los Angeles, California. (Botany).
*Bartow, Edward, Ph.D., University of Illinois, Urbana. (Chemistry).
Barwell, John William, Waukegan. (Anthropology).
Bassett, Herbert, Macomb, Ill. (Geography and Geology).
*Bayley, W. S., Ph.D., University of Illinois, Urbana. (Geology).

*Charter Members.

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Bensley, Robert R., M.B., University of Chicago, Chicago. (Anatomy).
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Berry, Daniel B., M.D., Carmi. (Medicine).
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Cox, Henry J., A.M., U. S. Weather Bureau, Chicago. (Meteorology).
*Crandall, Charles S., M.S., University of Illinois, Urbana. (Botany).
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Pfeiffer, Miss W. M., Ph.D., University of Chicago. (Botany).

*Charter Members.

†Died August 13, 1915.

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Pogue, J. E., PhD., Northwestern University, Evanston. (Geology).
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*Smith, Isabel Seymour, M.S., Illinois College, Jacksonville. (Botany).
Smith, Jesse L., Supt. of Schools, Highland Park.
*Smith, L. H., Ph.D., University of Illinois, Urbana. (Chemistry).
Smith, Orrin H., High School, Champaign. (Physics).
Smith, Sidney B., B.S., R. R. No. 9, Springfield. (Farming).
Smith, Wilbur, 5636 Kenmore Ave., Chicago. (Botany).
Snyder, John F., M.D., Virginia. (Archaeology).
Sorgatz, George F., M.D., State House, Springfield. (Medicine).
Southworth, Eva., B.S., 419 College Ave., DeKalb. (Geography).
*Starr, Frederick, Ph.D., University of Chicago, Chicago. (Anthropology).
Stevens, Frank L., Ph.D., University of Illinois, Urbana. (Plant Pathology).
Stevenson, A. L., Principal Lincoln School, 1308 Morse Ave., Chicago.
*Stewart, H. W., University of Illinois, Urbana. (Agronomy).

*Charter Members.

Stieglitz, Julius, Ph.D., University of Chicago, Chicago. (Chemistry).
Stillhamer, A. G., Bloomington. (Physics).
Stock, H. H., E.M., University of Illinois, Urbana. (Mining Engineering.)
Stowe, Herbert, M.D., 4433 Lake Ave., Chicago. (Medicine).
*Strode, W. S., M.D., Lewiston. (Medicine).
Strong, R. M., Ph.D., University of Chicago, Chicago. (Zoology.)
Swarth, H. S., University of California, Berkeley, Calif.
Sykes, Miss Mabel, B.S., S. Chicago High School, Chicago. (Geology).
Talbot, Marion, LL.D., University of Chicago, Chicago. (Sanitation).
Tandy, M., Dallas City. (Biology).
*Tanquary, M. C., Ph.D., Kansas State Agricultural College, Manhattan, Kansas. (Zoology and Entomology).
Tatnall, Robert R., Ph.D., Syracuse University, New York. (Physics).
Tedesche, Rabbi Sidney S., 452 W. S. Grand Ave., Springfield.
Thompson, David G., B.S., 1629 Hinman Ave., Evanston. (Geology.)
Tiffany, Hanford, State Normal School, Charleston. (Botany).
Tower, W. E., Englewood High School, Chicago.
*Townsend, E. J., Ph.D., University of Illinois, Urbana. (Mathematics).
Transeau, E. N., State Normal School, Charleston. (Botany).
Trapp, A. R., M.D., Ill. Nat'l Bank Bldg., Springfield. (Medical Diagnosis).
Tsou, Y. Hsuwen, Box 78, University Sta., Urbana. (Entomology).
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Udden, Anton D., Augustana College, Rock Island. (Physics and Mathematics).
Umbach, L. M., Northwestern College, Naperville. (Botany).
Van Alstine, E., Experiment Sta., Urbana. (Chemistry).
Vestal, A. G., University of Chicago, Chicago. (Ecology.)
Wager, R. E., State Normal School, DeKalb. (Biology.)
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Washburn, E. W., Ph.D., University of Illinois, Urbana. (Chemistry).
Waterman, Warren G., A.M., Knox College, Galesburg, (Botany.)
Webb, J. M., U. S. Bureau of Mines, Urbana.
Weber, H. C. P., Ph.D., University of Illinois, Urbana. (Chemistry).
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*Weller, Stuart, Ph.D., University of Chicago, Chicago. (Paleontology).
Wells, C. C., B.S., 1006 So. Michigan Ave., Chicago. (Chemistry).
Wells, M. M., S.B., University of Chicago, Chicago. (Zoology.)
Westcott, O. S., Waller High School, Chicago.
Whitney, Worallo, Bowen High School, Chicago. (Botany).
Wilczynski, E. J., Ph.D., University of Chicago, Chicago. (Mathematics).
Williston, S. W., M.D., Ph.D., University of Chicago, Chicago. (Paleontology).
Wilson, R. E., Ph.M., 2015 Sherman Ave., Evanston. (Mathematics).
Windsor, Mrs. P. L., 609 Michigan Ave., Urbana (Entomology).
Winslow, Charles A., 2125 Sherman Ave., Evanston. (Geology).
*Winter, S. G., A.M., Illinois Wesleyan, Bloomington. (Histology).
Wirick, C. M., A.M., Crane Technical H. S., Chicago. (Chemistry)
*Wood, F. E., A.B., Wesleyan University, Bloomington. (Zoology).
Woodburn, Wm. L., Northwestern University, Evanston. (Botany).
Woodruff, Frank M., Chicago Acad. of Sci., Chicago. (Taxidermy).
Wright, E. M., Albion. (Aquatic Biology).
Young, Abram Van Epps, 2020 Orrington Ave., Evanston. (Chemistry).
Young, G. B. M.D., 710 City Hall, Chicago. (Sanitation).
Young, Mrs. J. D., B.L., 4752 Vincennes Ave., Chicago. (Biology).
Zelany, Charles, Ph.D., 606 Matthews Ave., Urbana. (Exper. Zoology).
*Zetek, James Ancon, Panama Canal Zone. (Entomology).

*Charter Members.

TRANSACTIONS

OF THE

Illinois Academy of Science

NINTH ANNUAL MEETING

Urbana, Ill., Feb. 18, and 19, 1916

VOLUME IX

1916

Published By The State

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Edited By

J. L. PRICER

1917

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Vice-President, H. E. GRIFFITH, Knox College, Galesburg.
Secretary, J. L. PRICER, State Normal University, Normal.
Treasurer, H. S. PEPOON, Lake View High School, Chicago.

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CHARLES ZELENY, Urbana.

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GEO. D. FULLER, University of Chicago, Chicago.
FRANK C. GATES, Carthage College, Carthage.

Committee on Secondary School Science

All members except J. C. Hessler, removed from the State or resigned.

Committee on Membership

A. R. CROOK, Springfield, Chairman.
H. C. COWLES, Chicago.
W. S. BAIN, Springfield.
R. E. WAGER, DeKalb.
CHARLES ZELENY, Urbana.

Committee on Preservation of Wild Life

R. E. WAGER, DeKalb, Chairman.
H. C. COWLES, Chicago.
H. S. PEPOON, Chicago.
FRANK SMITH, Urbana.

PAST OFFICERS OF THE ACADEMY

1908

President, T. C. Chamberlin, University of Chicago.
Vice-President, Henry Crew, Northwestern University.
Secretary, A. R. Crook, State Museum of Natural History.
Treasurer, J. C. Hessler, James Millikin University.

1909

President, S. A. Forbes, University of Illinois.
Vice-President, John M. Coulter, University of Chicago.
Secretary, A. R. Crook, State Museum of Natural History.
Treasurer, J. C. Hessler, James Millikin University.

1910

President, John M. Coulter, University of Chicago.
Vice-President, R. O. Graham, Illinois Wesleyan University.
Secretary, A. R. Crook, State Museum of Natural History.
Treasurer, J. C. Hessler, James Millikin University.

1911

President, W. A. Noyes, University of Illinois.
Vice-President, J. C. Udden, University of Texas.
Secretary, Frank C. Baker, Chicago Academy of Science.
Treasurer, J. C. Hessler, James Millikin University.

1912

President, Henry Crew, Northwestern University.
Vice-President, A. R. Crook, State Museum of Natural History.
Secretary, Otis W. Caldwell, University of Chicago.
Treasurer, J. C. Hessler, James Millikin University.

1913

President, Frank W. DeWolf, State Geological Survey.
Vice-President, H. S. Pepoon, Lake View High School, Chicago.
Secretary, E. N. Transeau, Eastern Illinois Normal School.
Treasurer, J. C. Hessler, James Millikin University.

1914

President, A. R. Crook, State Museum, Springfield.
Vice-President, U. S. Grant, Northwestern University, Evanston.
Secretary, Edgar N. Transeau, Eastern State Normal School, Charleston.
Treasurer, J. C. Hessler, James Millikin University.

1915

President, U. S. Grant, Northwestern University, Evanston.
Vice President, E. W. Washburn, University of Illinois, Urbana.
Secretary, A. R. Crook, State Museum, Springfield.
Treasurer, H. S. Pepoon, Lake View High School, Chicago.

Minutes of the Ninth Annual Meeting

REPORT OF THE SECRETARY

The Academy was called to order in the National History Building at 2:10 p.m. Friday, February 18, 1915, by President Grant. Dr. T. J. Burrill, of the University of Illinois, gave an address of welcome, which appears farther along in the volume. After announcements by C. R. Richards, chairman of the local entertainment committee, the Treasurer presented his report, which is given in full below. This report was accepted and a committee was appointed to audit the books.

The Secretary's report for the eighth annual meeting was read and approved. This report is printed in Volume VIII of the Transactions. The Secretary then read the report of the Council meeting of the year as follows:

The Council meeting was held June 29, 1915, at the University Club, Evanston. There were present the following members: U. S. Grant, A. R. Crook, H. S. Pepoon and Henry Crew. It was voted to accept the invitation of the University of Illinois to hold the ninth annual meeting at Urbana, February 18 and 19, 1916, and the program was tentatively arranged. The Treasurer announced total receipts amounting to $348.44, expenditures of $79.29 and a balance on hand on June 29, 1915, of $269.15.

L. C. Raiford and J. H. Beal were elected to membership and resignations were received and accepted from J. H. Harper, I. O. Baker, H. T. Mortensen and S. E. Young.

Several plans were considered for raising funds with which to publish back volumes of Transactions, but no action was taken.

For the committees on legislation and publication, A. R. Crook stated that the publication of Volumes VII and VIII had not been possible because the efforts of the committee on legislation had not met success. Every member of the committee had done what was possible to secure State aid, but the bill passed by the Legislature had not received the Governor's signature. The committee felt, however, that since such assistance is customary in all European countries and quite general in neighboring states and so beneficial for the whole State, that at the next attempt it would meet with better fortune.

No report was presented by the Calendar Committee or by the Committee on Secondary School Science.

G. D. Fuller, chairman of the Membership Committee, presented a list of twenty-one candidates for membership and all were elected.

S. A. Forbes presented a report for the Committee of Ecological Survey. This report is given in full below.

The president appointed the following committees:

Auditing Committee, E. J. Townsend, F. W. DeWolf, A. W. Slocum and L. E. Hildebrand.

Nomination Committee, S. A. Forbes, Philip Fox, Stewart Weller, J. C. Hessler and T. L. Hankinson.

Resolutions Committee, Stewart Weller and J. C. Hessler.

The Secretary presented a communication from U. S. Congressman Albert Johnson relating to H. R. 528 concerning the discontinuance of the Fahrenheit scale in government publications. On motion of A. W. Noyes, seconded by J. C. Hessler, it was voted that the use of the centigrade scale be adopted in all U. S. government publications at the earliest possible moment and the Secretary was directed to forward this resolution to the Thermometer Committee of the A. A. A. S. Bureau of Standards.

Following the business session, the Symposium on Astronomy and several general papers were presented.

At 7:30 p. m. a reception was tendered to the Academy by the Illinois Chapter of Sigma Zi in the Woman's Building, and this was followed by a symposium on the policy, aims and value of the Academy. The speakers on this symposium were: President E. J. James, O. C. Farrington, H. E. Griffifth, Frank DeWolf, W. A. Noyes, E. W. Washburn, H. B. Ward and William Trelease. Some of the speakers frankly admitted that the Academy had not yet achieved the success that had been hoped for, but all were optimistic concerning the future possibilities and all pledged a renewed devotion to the purposes for which the Academy was established.

The Academy met again at 9:00 a. m. on Saturday, February 19, for a general session, at which nine papers of a general nature were presented, and then the Academy was divided into sections for the presentation of papers as follows:

Section of Botany and Bacteriology. H. S. Pepoon, chairman; J. L. Pricer, secretary.

Section of Zoology and Medicine. J. S. Kingsley, chairman; A. MacGillivray, secretary.

Section of Physics and Engineering. E. W. Washburn, chairman; C. T. Knipp, secretary.

Section of Chemistry and Agriculture. W. A. Noyes, chairman; Edward Bartow, secretary.

Section of Geology and Geography. W. S. Bayley, chairman; A. W. Slocum, secretary.

A complimentary luncheon was served to the members of the Academy at 12:30 p. m. by the Illinois Chapter of Sigma Zi, and at 2:00 p.m. the section meetings resumed.

Upon the completion of the section meetings, a general session was held, at which Dr. H. M. Whelpley of St. Louis delivered a special lecture on the subject, "The Landlords Whom We Have Evicted."

This was followed by a business session for the reports of committees and the election of officers.

The Auditing Committee reported that the accounts of the Treasurer had been examined and found correct. The suggestion was made that in the future the Treasurer submit to the Auditing Committee all of the following items: Statements of expenditures and receipts, vouchers showing all payments, and bank book showing deposits.

The Nomination Committee proposed the following for officers and committeemen, and upon motion, the Secretary was instructed to cast the ballot and the President declared them elected:

President, William Trelease, Urbana.

Vice President, H. E. Griffith, Galesburg.

Secretary, J. L. Pricer, Normal.

Treasurer, H. S. Pepoon, Chicago.

Member of Publication Committee, W. S. Bayley, Urbana.

Committee on Membership, A. R. Crook, Springfield, chairman; H. C. Cowles, Chicago; W. S. Bain, Springfield; R. E. Wager, DeKalb; Charles Zeleny, Urbana.

On motion of R. E. Wager, it was voted that the Academy undertake the wardenship and possible acquisition of such portions of the State as still offer opportunity for the preservation of wild life typical of its flora and fauna. The following committee was appointed to consider this matter and report at the next meeting: R. E. Wager, chairman; Henry C. Cowles, H. S. Pepoon and Frank Smith.

The following resolution was presented by Stewart Weller for the Committee on Resolutions:

In the closing hour of the ninth annual meeting of the Illinois Academy of Science, the members of the organization desire to express their deep appreciation of the hospitality afforded by the University of Illinois. The nonresident members wish especially to express their obligations to the resident members of the Academy for their constant oversight of the needs and comforts of the visitors and to the local Chapter of Sigma Zi for their most delightful entertainment.

We feel that the meeting has been most successful and are confident that the interchange of ideas and the renewal of social relations between members from different portions of the State will give everyone of us added enthusiasm in our special fields of labor. We also believe that the future usefulness of the Academy will be greatly accelerated by reason of the expressions which have been made of the aims and purposes of the organization.

The Academy further wishes to express its deep appreciation of the efficient services which have been rendered by the outgoing officers.

STEWART WELLER,
J. C. HESSLER,
Committee.

The ninth annual meeting of the Illinois Academy of Science then adjourned.

A. R. CROOK, Secretary.

REPORT OF THE TREASURER

February 18, 1916.

RECEIPTS

Received from J. C. Hessler (ex-Treasurer)	$294.94
Received from initiation fees	6.00
Received from membership fees	145.50
Total receipts	$446.44

EXPENDITURES

A. R. Crook, postage	$ 20.00
A. J. Patterson, postage	1.24
Dr. William Barnes, postage	1.62
T. L. Hankinson, postage	1.76
E. O. Jordan, postage	.24
E. N. Transeau, closing 1915 account	10.52
Charleston Courier, printing	32.00
A. L. Tracy, cards, statements	5.75
J. E. Schwatal, postage	4.00
Mrs. H. S. Pepoon, postage, exchange, envelopes	2.16
Ed. Hartmann Co., stationery	16.00
A. R. Crook, postage	10.21
H. S. Pepoon, postage, exchange, nvelopes	2.90
A. R. Crook, postage	10.00
Ed. Hartmann Co., stationery	12.25
Albert Carver, lantern fee 1915	5.00
J. W. Guest & Co., printing	3.00
Total expenditures	$138.65
Balance on hand February 18	$307.79

H. S. PEPOON, Treasurer.

REPORT OF THE COMMITTEE ON AN ECOLOGICAL SURVEY OF THE STATE

To the Illinois Academy of Science:

Your Committee on an Ecological Survey has to regret the removal from the state of three of its members: Dr. C. C. Adams, of the University of Illinois; Dr. E. N. Transeau, of the Eastern Illinois State Normal School, and Mr. F. C. Baker, formerly secretary of the Chicago Academy of Sciences. On the other hand, your chairman, acting upon the privilege accorded him when the committee was constituted, has added to its membership Dr. A. G. Vestal, who succeeds Dr. Transeau at Charleston, and Dr. F. C. Gates, now of the botanical department of Carthage College, at Carthage, Ill.

An important contribution to a knowledge of our field, now nearing its completion, is the work on the flora of the Chicago area by Dr. H. S. Pepoon. He reports as finished an annotated list of the plants of the area; a chapter by Professor Hill on the "Southern District," extending from the Des Plaines River to Gary; and chapters on the "Waukegan Sand Moor," the "North Shore Ravines" and the "Des Plaines River Valley." Chapters on the "Western Moraine," by Dr. Pepoon, and one on the "Sand Dunes," by Professor Cowles, will soon be complete. The region covered by this report includes the drainage basin of Lake Chicago and the adjacent highlands of the Valparaiso moraine, in a district comprising many types of ecological formation and illustrating in a remarkable manner many problems of distribution, topography, effect of glacial agencies, the introduction of new species, and the destruction of old. The finished work will contain full notes on about nineteen hundred species, descriptions of each of the six natural districts in the area illustrated by maps on a large scale, fifty characteristic photographs, and many tables, diagrams, and charts. It is believed that the finished flora will be one of the most complete ever attempted for any locality.

Another work of peculiar interest is an ecological survey of the vegetation of Illinois prairies, made by Homer C. Sampson, working as the agent of the botanical department of the University of Chicago and the State Laboratory of Natural History acting in co-operation. Mr. Sampson makes the encouraging statement that there are still thousands of acres of native prairie remaining in the state, about two thousand, indeed, within the city limits of Chicago, so little disturbed by man that they are available for ecological studies. He is studying the composition and succession of the plant associations characteristic of the different kinds of prairie in this state, and the data obtained have led him to the following general tentative conclusions:

1. Starting with the various pioneer habitats of the prairie regions of Illinois, as the physiography of these habitats develops, there follows a dynamic succession of associations of prairie plants; the associations differing in each particular case according to the initial habitat but ultimately all merging into a temporary climax type of prairie.

2. *Andropogon furcatus* in general is the most abundant grass on this temporary climax prairie; a fact suggesting that it may be the mesophytic climax grass of this region.

3. The above data support the theory that the black-soil prairies of Illinois originated in glacial lakes and swamps and have existed as prairie since glacial times.

4. In a large general way the trend of the associations on the black-soil and clay prairies follows the change in moisture content of the soil as the physiography of the region develops.

Additional studies in this field have been made by Dr. A. G. Vestal, who has worked out the status of the prairie relics in the sand dunes of Lake Michigan with special attention to lines of contact between the prairie and black-oak formations; and by Mr. Hankinson, who has continued his studies on the animal life of the prairie remnants of Coles county and neighboring districts.

Further studies of our aquatic biology have been made by the State Laboratory of Natural History, which has brought to a practical conclusion its long course of work on the Illinois River and the lakes of its bottom lands. The principal work of the last season has been the making of over five hundred collections from the bottom, by means of dredges, mud dippers, and the like, in various localities from Peoria to the mouth of the stream, intended mainly to verify conclusions drawn from the studies of previous years.

Mr. Hankinson has continued his observations of the fishes of the streams of his neighborhood, especially with reference to their breeding dates and habitats.

Dr. Shelford has continued his extremely interesting and important experimental studies on the reactions of fishes to certain features of their environment, analyzed and isolated by means of an ingenious apparatus which he has devised. His most recent work has been upon the effects of the wastes of gas plants upon the fishes of a stream, a subject which he is to treat in a paper on our present program.

It will be seen that our original committee on an ecological survey has itself virtually become the agents of such a survey, so far as this is practicable under our present conditions; and it is our intention to annex to our membership all active workers in this field, and to plan as we go methods of co-operative organization which will give a unity to our undertakings not possible in the beginning. Respectfully submitted,

S. A. Forbes, Chairman.

Addresses

ADDRESS OF WELCOME

T. J. Burrill, University of Illinois

Mr. President and Members of the Academy:

I esteem myself fortunate in having the privilege of offering to the officers and members a few words of welcome to this place and to the University, within whose walls we are gathered. President James would have gladly done this, but always has many calls upon his attention and time at home and abroad. It seems the world is his parish and he magnifies his office.

It is a great pleasure to us all that you meet here, especially because you are among those who are best contributing to the upbuilding of our splendid commonwealth. It is such studies and investigations as you are making that have made the phenomenal material and humanistic advancement now witnessed and are to make the further improvements assuredly on the way.

The area of Illinois is no larger now than it was forty-nine years ago, when the University of Illinois was chartered and located. The soil is no better now than then, the vast deposits of coal were as vast then, the forests the State over are certainly no better; but marvellous things have happened within the time mentioned. Then it was easy to reach from where you now sit, by horseback in an hour or less, areas of the great native or original prairies from points of which on the clearest day not a tree or a house was to be seen. There were large areas of this open prairie, too wet for tillage, that were offered for sale as low as $1.50 an acre, land that now, without much outlay meanwhile, commands $200 or more. Men never dreamed in those earlier days or nights that floating dredge machines would burrow their way through and across these level, water-soaked plains. The Illinois Central engines were burning wood, waiting better adaptations for coal, of which the enormous supplies were little appreciated. And to suggest a greater difference the trains were run by time card, instead of telegraphic help, waiting in case of a miss at a meeting station thirty minutes and then proceeding with the understanding that the track would be clear to the next station. The man who wrote the contracts for the Western Union Telegraph Company with the railroads for the use of the wires by the latter was for twenty years a trustee of this University (beginning in 1867), and but for an accident might have still been living, so recent was that contract.

Populations have increased, wealth has multiplied again and again, business has grown beyond the wildest imagination of the earlier day, living conditions have wonderfully improved, our material inheritance has become much better known, opportunities are better used, and we may well believe better human lives are lived—all because of the revelations and additions made by men and women like yourselves, people whose activities have been and are generously devoted to the common good.

The printed program I hold in my hand shows an amazing array of subjects to which your attention is to be given. It may well be that something said or done during this meeting will be noteworthy for all time, something from which dates will begin, something epoch making. Whether this shall be so or not, the spirit of your work leads in such direction and the State Academy of Science engenders and fosters such discoveries and improvements.

I have now, Mr. President, only to repeat that the University of Illinois heartily welcomes the members of the Academy to this place, to our twin cities, to the campus and all that is thereon. And it is hoped that this meeting will be so pleasant and so successful that you will all want soon to come again.

LIFE AND WORK OF JOHN ULRIC NEF

Julius Stieglitz, University of Chicago

On August 13 the Academy suffered the loss of one of its most eminent members through the death, in the prime of his life, of John Ulric Nef, head of the department of chemistry of the University of Chicago. Professor Nef's life was marked by its simplicity, the simplicity which is characteristic of real greatness—it stood for but a few things—but each was a great purpose in itself. He will be remembered by many in this generation as a man of wonderful intensity of purpose, of unswerving honesty of mind and unselfish devotion to his friends. He will be remembered by hundreds of his students as a great teacher, one who stimulated them to think for themselves and to test their thoughts in the crucible of critical experimentation. But in this generation and far beyond it, his name will stand longest as that of a great investigator, who contributed his share to the foundation stones of the science of chemistry. From the earliest years of his career, as professor of chemistry at Purdue University and then at Clark University, and during the twenty-three years of his connection with the University of Chicago, his devotion to research was unique for the intensity and the single-hearted ardor with which he gave almost every ounce of his strength, almost every thought to his problems. Perhaps his greatest work—the work which secured immediate recognition—was that of overthrowing the belief that the carbon atom must always have a valence of four—a belief which had become practically an article of faith through the work and ideas of Kékulé and his followers. Nef's proof that isocyanides and fulminates show all the properties which one could postulate for a bivalent carbon atom opened a new field of thought, a new interpretation to many chemical reactions, the effect of which will always be felt in the development of the science. In his own hands, it opened the way for an attack on the problem of the chemistry of the sugars that promises much for our progress on the path toward explaining the use of carbohydrates in life phenomena.

The seeds of his thoughts have already found productive soil in the minds of other able workers and his immediate problems will undoubtedly be carried on by a number of his younger collaborators; but the world has lost the courageous mind, the intense driving power and the critical imagination which together made John Ulric Nef a genius in his field of work.

Symposium on Astronomy

STELLAR PHOTOMETRY

By Joel Stebbins

In measures of the light of stars we are not concerned with absolute intensities, but rather with how the light of a heavenly body varies. If the light is constant, there is not much to be learned, but if it changes, we may infer a great deal from the law of variation. In laboratory and commercial photometry, it is customary to measure what may be called the visual brightness of a source of light, but with the stars it is immaterial for many purposes whether we study the changes of the red, or the blue, or any other part of the spectrum, though in fact any complete stellar photometry should include measures in all regions, infra-red, visible, and ultra-violet.

The chief disadvantage in stellar photometry is that the stars are so faint that it is usually not feasible to expand their images out into surfaces, and most forms of stellar photometer depend upon comparisons of two point images by the eye. Although the eye is a wonderful instrument, especially in the range of intensity over which it may be used, the limit of accuracy attained by looking first at one light and then at another is much the same as though instead of using a balance we should weigh objects by lifting them in our hands. It is safe to say that no observer has been able to get visual results accurate to 1 per cent, and in the best measures there are occasional errors of 10 per cent, 20 per cent, and even more. It was hoped that the introduction of photography would bring greater accuracy in stellar photometry, but at present the errors of the best photographic measures and of the best visual ones are about the same.

For a number of years we have been interested at our observatory in the development of an electrical method for the measurement of star light, based upon the property of the peculiar substance selenium. There is another device, however, which bids fair to supplant entirely the selenium photometer, namely the photo-electric cell made from one of the alkali metals. The principle of each of these devices is the conversion of a light effect over into a minute electric current which can be measured by a galvanometer or electrometer. In the photo-electric cells we use one of the metals sodium, potassium, rubidium, or caesium. The sensitive metallic surface is in an exhausted tube with a small quantity of inert gas, and the effect of light is to release electrons, which ionize the gas, and thus a current is produced. We are fortunate in having several of our physicists at the University of Illinois interested in photo-electric cells, especially Professor Jacob Kunz, and it is in the laboratory where the really important improvements are made. When we produce a cell which is twice as good as anything we have had before, this amounts to the same things as though some good fairy had suddenly doubled the light-gathering power of our telescope. There are certain advantages of the photo-electric cell over selenium, and while it is too soon to make a final estimate of the relative sensibility, the newer device is already five or six times as sensitive as the best we have ever had with selenium, and we expect a still further improvement.

The extreme sensibility required becomes apparent when we state that the image of a second magnitude star, say the Pole Star, near the focus of our twelve-inch telescope objective gives the same surface illumination on a photo-electric cell that would come from a candle at 500 meters' distance, without any intervening lens. Therefore to measure the light of such a star with a probable error of 1 per cent is equivalent to the detection of a candle at 5,000 meters, or roughly three miles.

We may now consider some of the applications to the stars, and although the results to be mentioned were all obtained with the selenium photometer, they could have been secured more easily with the photo-electric instrument if that had been available.

There is one star in the sky which for a hundred years has aroused more interest than any other, namely, the well-known variable, *Algol.* Once in sixty-nine hours the star is found to lose two-thirds of its light, due to the eclipse of the main body by a large and relatively faint companion. This principal eclipse has been known and studied for a century, but it has often been pointed out that if the eclipse theory is true then, unless the companion is entirely dark, there should be a second eclipse when it passes behind the main body. This decrease in light midway between the primary eclipses was sought for in vain by visual observers, but observations with the selenium photometer established the presence of a diminution amounting to 6 per cent. There is also a continuous variation between minima, showing that the companion is brighter on the side toward the primary, partly because of reflection, but chiefly because of the heating effect. As the brighter body gives off more than 200 times as much light as the sun, it is easy to show that on the surface of the companion nearest the primary there is received more radiation per unit area than is emitted by the sun, and even on its fainter side, this body, which has often been called dark, has much more than the solar intensity. The scale of miles is not exactly known, but each body has slightly more than the solar diameter, the companion being a trifle the larger, and the distance between centers is less than five times the average radius of the spheres.

Another case is the second magnitude star, β *Aurigae,* which was one of the first of the so-called spectroscopic binaries to be discovered. As the spectrum lines are single and then double on successive nights, we have a system of two bodies with a period of revolution of about four days. The bodies will be in conjunction as seen from the earth when the spectrum lines are single, and this is the time to look for eclipses. The photometric observations show that exactly at the predicted times the light of the system decreases 7 per cent, the eclipses following each other at intervals of half the period. We have then a twin system, each component having 2.6 times the diameter of the sun, 2.4 times the mass, and being 1/7 as dense. The surface brightness of each body is at least 12, and possibly 25 times that of the sun, the total light of the system being 150 to 300 times the solar light. Therefore the sun if placed beside these dazzling objects would look like an insignificant dark body.

The next star which has been observed is δ *Orionis*, the right hand one of the three in the Belt of Orion. This object has given us a great deal of trouble, and we have spent something like 200 hours at the telescope in an effort to smooth out some of the irregularities in the light curve. There are two eclipses, one of 8 and the other 7 per cent, showing that the companion is nearly as intense as the primary. There is also a variation due to the ellipticity of the orbit, the two bodies being brighter when they are nearer together as a result of a tidal or heating effect. The larger body must have five times and probably does have fifteen times the solar diameter, while the companion is of half the linear size of the primary. The total mass of the system may be twenty times the sun's, and we can say definitely that the mean density of the system is 0.006 on the solar standard, that is, the bodies average only six times as dense as air. A fair estimate of the total light is that it is equal to 5,000 suns.

These three stars, *Algol, β Aurigae and δ Orionis* represent three types of eclipsing binary. The first has a large faint companion, in the second there are twin components, while in the last case the bodies are unequal in size but nearly equal in intensity. As these were actually the first three stars studied with the selenium photometer, and something new came out of each, it is evident that there is plenty of work to be done on similar objects of which there are thousands in the sky. There are at least two other variables which we have picked up, α *Coronae Borealis,* and the bright star *Spica.*

In fact the large proportion of stars which are variable brings up a number of questions. We may study a large number of stars and find a certain number of eclipsing variables. The proportion of variables gives the probability of such discoveries in a further search, but also we can say that for every variable found there are a definite number of other binary systems the planes of whose orbits are inclined so that we miss the eclipses altogether. From considerations of this nature, it has been possible to conclude: The preponderant type of close binary with components of the same order of size, and of equal or unequal brightness, consists of bodies whose distance between centers is approximately five times their average radius, whose period of revolution is about four days, and whose mean density is 1/20 that of the sun. Systems of greater or less relative separation are not so numerous, or we should find more of them among the eclipsing variables. This particular discussion is based upon the variables which have been found by visual and photographic methods, but there is abundant field for work in the same line for the electrical photometers. The point to emphasize is that not only will systematic studies of stars which vary in light give us direct information, but indirectly we can draw far reaching conclusions about stars which are apparently constant.

Of the many other problems in photometry which may be attacked with good prospect of success may be mentioned the case of our sun, which, according to Abbot, is a variable star. There can not be the slightest doubt of the variation, for a single sunspot is enough to change the total light, the only question is how much? However, the changes in the light are probably measures of the general activity of the sun, rather than of local disturbances like spots. In direct measure of the sun's radiation the chief difficulty lies in the proper allowance for the absorption of the earth's atmosphere, but this trouble may be eliminated by comparing the reflected solar light from one of the planets with the light of a number of stars. Probably Saturn is a good object for this purpose, as there are few markings on its surface, but Uranus would be still better on account of its slower motion, and the greater number of comparison stars which could be found for it.

In the present paper, an attempt has been made to indicate in a general way the work we are doing, and evidently there is considerable variety in it. The production of a good electric cell, and its proper installation in a photometer is a problem in experimental physics, and any success which has come has been through the efforts of several men of widely different training and interests. In the experiments with selenium I had the collaboration of Dr. F. C. Brown, and now, with photoelectric cells, Professor Jacob Kunz is doing his best to perfect our methods. By combining our knowledge and experience we have been able to carry on researches which would have been hopeless for one man alone.

THE DETERMINATION OF STELLAR DISTANCES

Philip Fox, Northwestern University

Dr. Fox spoke without prepared manuscript. His address contained a review of the methods of determining stellar distances with comparison of the accuracy of various methods, and indicated directions in which our knowledge of the arrangement of stars in space has been extended as a result of these investigations

General Papers

PURIFIFCATION OF SEWAGE BY AERATION IN THE PRESENCE OF ACTIVATED SLUDGE

EDWARD BARTOW, SANITATION SERVICE, FRANCE

ABSTRACT

By blowing air into sewage, then allowing the suspended matter to settle and decanting the supernatant liquid, adding fresh sewage and repeating the operation, there is accumulated sludge which has the property of purifying sewage in the presence of air in from four to five hours. The sludge obtained contains more nitrogen than sludge obtained by any other method of sewage purification. It has been shown by analyses and by experiments with growing plants that it is valuable as a fertilizer. By the process bacterial reduction of 95 to 99 per cent is affected. The cost of the process depends upon the cost of producing air. It has been estimated that it will be the most effective and most economical method of sewage purification. This will be especially true if the sludge can be readily recovered and disposed of for use as a fertilizer. Plants of considerable size have been constructed at Milwaukee, Cleveland and Champaign, and the process will be given a thorough trial.

Complete paper published in the Journal of the Boston Society of Civil Engineers, Vol. 3, No. 4, April, 1916, under the title, "The Latest Method of Sewage Treatment."

TESTS ON THE COMPARATIVE FRIABILITY OF ILLINOIS COALS AND THEIR PRACTICAL APPLICATION

ABSTRACT

L. A. MYLINS, UNIVERSITY OF ILLINOIS

PROBLEM

The comparative friability of Illinois coals refers to the comparative tendency among them to produce fines or breakage or degradation products under like conditions. In mining and marketing coal the excessive handling needed shatters some coals more than others. Commercially this is of great importance, since in general a reduction in size or an increase in fines in the coal means a distinct loss in value. The problem, therefore, was to test Illinois coals from the different districts, under varying conditions, to discover any laws governing this breakage, and to establish some standard of relative friability by which the reduction in market value due to degradation might be impartially estimated.

PROCEDURE

The procedure involved a search of literature on the subject and a study of any methods and apparatus which had been used previously. After testing some of these methods they were rejected as unsuited to the problem, and new apparatus devised.

A drop test machine was constructed, in which a box filled with 50-100 pounds of the coal to be tested and provided with a gate on the bottom is elevated to any height up to ten feet above the floor.

The gate is opened suddenly and the coal falls to the floor, which may be wooden, steel or concrete. By screening this coal through a standard set of screens the breakage of the larger sizes into the smaller is determined quantitatively. A great deal of care is necessary in manipulation to secure results which are in agreement.

RESULTS

The results have shown a surprising individuality among different coals in regard to their comparative friability. It seems possible to give definite coal of definite size a fixed comparative friability factor. The difference among Illinois bituminous coals in themselves is about as great as between anthracite and the least friable of the Illinois coals. A great difference was noted as to the material of the floor on which the falling coal struck. Steel and concrete causing much more breakage than wooden floors or bins. The size of the coal and the amount of moisture present in the coal are other important factors. For example, it was found possible to place coal in water for a minute or two and greatly reduce the amount of breakage.

FUTURE WORK

Further testing work is necessary to definitely fix additional points on the curves that are being plotted. The work should be extended to show the effects of weathering, of handling in larger or smaller lots, and from pressure, etc., in passing through bins and stock piles. Finally, it is hoped to deduce formulae by which breakage can be calculated for the actual conditions of commerce.

PHOTOGRAPHING FLOWERS AND INSECTS

Arthur G. Eldredge, University of Illinois

Photography has become of great assistance to science; it is no longer an uncertain curious process; its application is unlimited and it reveals many things which the eye might never see. If we combine it with an interest in the natural sciences such as botany, zoology, entomology, etc., we are led into a sphere where wonders never cease. It takes us out into the sunshine of the broad fields beneath the blue sky, to the cool shades of the forest, into the silent places where we may contemplate the beauty and be refreshed. It fairly makes a vagrant of us until the confinement of walls and doors becomes oppressive.

I have found occasion to do much tramping about in quest of wild flowers as photographic subjects. To walk long distances in warm weather with twenty pounds of equipment is not a pleasure except to those who find an interest in the work.

Flowers appeal to me from three points of view as subjects for the camera. First, the landscape effect of infinite numbers; second, a near view showing the plant sufficiently for identification and at the same time showing its typical manner and place of growth; third, a portrait of the flower with sufficient foliage to make a pleasant picture and also indicate the species. The first condition is less difficult to render than the other two. The second condition would seem to be the most important and a photograph in which that condition is not fulfilled loses much of its value as a record of facts. A botanist is interested in a photograph which will answer the question, Where does the plant grow? Plants frequently grow in many places which are not a *type* location. It is for us to realize this even though it cause much weary search, or we may not record the facts. I may say from experience that sometimes the search is long, though often well rewarded. The prairie region contains many distinctive plants not found naturally elsewhere. Once very abundant they are now hard to find if not already exterminated by the invasion of agriculture. The sun loving flowers are restricted chiefly to the steam or electric right of way or to bits of unused land. The shade loving varieties have been less disturbed, particularly in the river valley, while the aquatics have suffered greatly by the drainage of prairie swales and sloughs.

The third condition is a patient task. The light is frequently from the wrong direction or there is sunshine when we would prefer shade. The wind seems incessant even on days that appear calm; this requires you to keep constant watch of the subject. These disturbing factors make the work much more difficult when large size photographs are made, as exposures of several seconds are necessary. Portraits of many flowers are better made growing; being difficult to revive after wilting, and some will not revive at all. However long the search for a desirable specimen may be or weary the wait to photograph it, you are rewarded by the pleasure of the search, and not the least is the satisfaction of the result.

The prairie rose (*R. Setigera*) is a lover of the open, yet it is often found elsewhere. I like to think of it as growing on the edge of expansive prairies and my search was rewarded with a satisfactory though not ideal example. The woodland phlox (*P. divaricata*) prefers a mixture of sun and shadow. It blossoms early before the shade is too heavy, growing out to the edge where woods meet prairie, rarely if ever beyond. So my search was for a specimen which would be near the edge of the woods. The compass plant (*Silphium laciniatum*) is very individual in habit, growing far above most of its neighbors, and it becomes very effective when silhouetted against a sunset sky. On consideration of each subject we may perhaps find some character of the plant which will portray it in a more individual way.

There is another side of flower life which offers an interesting use for the camera; it is that of the insect visitors. There is a great variety of insects and they come for many purposes; some for pollen, some for nectar, some to eat the flower itself, others to lie in wait to commit murder. Nature often calls with a double purpose when she beckons with vivid color or far reaching perfume, as many flowers must be pollinated by the insects. A well known example is genus *Asclepias,* known as milkweed. Some varieties prove to be an insect trap because of the peculiar mechanism of the flower. A common milkweed known as *Asclepias syriaca* has been selected because it seems to catch more insects than the other species. First it has an alluring odor, delicious and spicy. In this way it draws large numbers of insects such as moths, butterflies, bees, flies and beetles. Its pollination must be effected by insects if at all. Standing on the flower to get nectar, the insect's feet fall into slits on the side and become engaged with the pollen masses inside. If the insect is not strong enough to remove his feet he is held captive by the flower and dies, if not eaten by his enemies or able to free himself by breaking a leg. Strong insects are able to remove their feet, usually extracting the pollen masses, which are carried to the next flower, causing pollination.

The flower and all of these events may be photographed with suitable apparatus and much patience. Magnified photographs with the camera bring many difficulties, perhaps easily overcome individually but when acting together are annoying and require much time to surmount. Some parts of this milkweed subject must be photographed through the microscope. The pollinia and the feet engaged in the trap may be brought up to almost any degree of magnification when carefully mounted in balsam. By the use of suitable plates and color screens facts are often revealed that otherwise might not be observed.

There are many fascinating books on insects and flowers. The subjects, although well explained, do not always convey the facts to one not familiar with them. The camera lucida gives results superior in some ways, yet inferior in others. There is a large field open in this branch of photography to those who have both patience and time.

A LABORATORY EFFICIENCY TEST FOR ADVANCED STUDENTS IN CHEMISTRY

David F. McFarland, University of Illinois

In recommending young graduates in chemistry and chemical engineering for positions in industrial laboratories and plants it is often desirable, if not imperative, to know something of their ability to do a large amount of work of more or less routine nature, neatly, accurately and acceptably, and their ability to work at times under high pressure without loss of accuracy or efficiency.

There is, unfortunately, little opportunity to measure these valuable traits with any accuracy in the usual laboratory work of the course. To be sure, much can be judged from the marked differences which are observable between the various individuals of a class in the neatness and accuracy of their work and in the promptness with which it is reported.

The daily class work can, however, scarcely be expected to afford favorable opportunity for tests of efficiency. The main object of the course is to teach fundamental principles, and standard or selected methods based on these principles. The attention of the students is focused upon these and not upon any ideas of economy of time, or real efficiency of operation.

It was with the view to developing some test or series of tests that would serve to measure the different members of graduating classes that the work herein described was begun five years ago.

It was inaugurated as a laboratory examination in a course in fire assaying in which 20 or 25 senior and graduate students are annually enrolled.

This course affords a considerable number of analytical determinations of the same general type and the student has an opportunity to learn fairly well the main details of procedure, the sources of error and how to avoid them, and the chances for saving time and labor.

An effort is made as the course proceeds to get him to plan his work with a view to efficient utilization of time and to watch for improvement in the technique of his operations.

No attempt is made, however, to assume that he can be made an expert assayer in the short time allotted to the course. That is manifestly impossible, and is not desirable for students of this class since very few of them expect to do any assaying after graduation.

The conditions of the "efficiency run," as the test was designated, were posted several days in advance.

Each student of a squad of five was to be given four finely-ground samples of ores, offering no exceptional difficulty of treatment, one day before the time of the run. He was to examine each sample carefully; make any blowpipe, vanning, or other tests which are needed to identify the minerals, and prepare a statement of the nature of the ore, its gangue and the charge which he intended to use upon it. He was allowed to stock up on materials and to put apparatus into condition, but was not permitted to make any weighing or to mix any charges.

At the time appointed for the test each contestant was given a furnace, ready heated to a proper working temperature, and the run was started. The control of the furnace thereafter was entirely in his hands.

The time of beginning and of the finishing of each stage of the assays was recorded by the instructor and records made of neatness, judgment of temperatures, (checked by the instructor's pyrometer), ability to keep up fires in the furnace, smoothness of operation, exhibition of patience or impatience, evidences of miscalculation or bone-headedness, etc.

Grading was made on the following scale: Accuracy, 35 per cent; neatness, 22.5 per cent; speed, 22.5 per cent; judgment of composition and treatment of ores, 10 per cent; judgment and control of temperatures, 10 per cent.

Reports were required to be neatly written upon blanks furnished for the purpose and the complete report had to be handed in before the run was considered finished.

Accuracy was estimated on the basis of average results obtained by the men of the same class under the more leisurely conditions of their previous work.

Of all the factors involved, the one of speed appealed most strongly to the individuals making the run, and from the first there was evidence of a tendency to reduce the whole test to one of speed.

With this in view, some wonderful systems of operation were devised, with shortcuts that were more or less fallible and often with difficulties quite unsuspected by the authors of the systems.

The failure of these systems brought out many individual peculiarities and revealed some temporary lapses in temper and nerve control. In some cases a slight accident to the assay would serve to upset a man's whole plan and leave him floundering and apt to do many foolish things.

A fine opportunity was afforded to study the ability of the contestants to work under fire and to detect their strong as well as their weak points.

In spite of frequent admonitions to the effect that "not to the swift is the race," the sporting instinct urged a speeding up, and the time records were rapidly broken again and again by successive squads and in succeeding years. An amount of work which required twelve or fifteen hours at least in their earlier career was turned out in a little over two hours by the speediest men.

The results were not so satisfactory, however, when judged from the *most* important angle of accuracy. Even when judged by the average of the current class, they were far from accurate as a rule. Moreover, penalties for gross errors of judgment, carelessness and noncontrol of temperatures, were more frequent than was desirable.

It was evident that the element of accuracy was rated too low, and a new scale of grading was used in this year's run, as follows:

Accuracy, 60 per cent; neatness, 15 per cent; speed, 15 per cent; judgment of ores and charges, 5 per cent; judgment of temperatures, etc., 5 per cent.

This has resulted in a very great improvement and has given some records that are highly satisfactory in accuracy as well as in other respects. The whole tone of the run has been raised and neatness has been enhanced. At the same time speed has not been lessened.

After five years of operation the test has shown itself of very great value both to the student and to his instructor.

It has fulfilled its object of affording a reasonable measure of the manipulative skill and judgment of the individual students and has been of use in describing these qualities to prospective employers.

By far the greatest benefit, however, has come to the students themselves in arousing their interest in the planning of their work to secure effciency, and in bringing about through this planning a much more thorough review of the whole subject matter of the course, than can be induced by any other method.

The various systems and plans of operation are vigorously discussed by the contestants before their runs and methods that succeeded with one are quickly adopted by others.

During the contests interested spectators gather on the side lines and discuss the chances of their "favorites" winning.

The posting of the final scores with their clear demonstration that speed without care and good judgment is a fruitless waste of endeavor, in an analytical laboratory, is very wholesome in its effects.

The principle of efficiency runs is one that can be utilized in many laboratory courses not only in chemistry but in numerous other subjects, and it is possible that its application in a number of lines might offer the best kind of data for a rational basis of recommending men for positions.

At any rate, it is commended to other teachers for trial.

SCIENCE AND MATHEMATICS

JAMES B. SHAW, UNIVERSITY OF ILLINOIS

That science has been dependent upon mathematics in many ways is so well recognized that it needs no comment. Sooner or later each branch of science develops a system of observational methods which assume numerical counting or the registration of numerical results of measure. These statistical results or quantitative results must then be discussed and their significance ascertained. It is true, of course, that there are other mathematical conceptions than those of numbers which enter largely into scientific work, but these cannot be discussed in the present paper. Such conceptions as vector, vectorline, dyadic, fields, whether scalar vector or dyadic, curl, divergence, line-integral, may involve numerical elements, but the essence of their characters is non-numerical. These, however, must be passed by in order to remain within the limits of time, and I desire to consider only one notion that science owes to mathematics and which appears in one way or another in practically every science.

The notion of scientific law rests upon the mathematical concept of functionality. In a law it is stated that a certain effect is to be expected from a given cause, or to be rather more technical and at the same time more exact, that a certain phenomenon called the effect is a function of a certain phenomenon called the cause. If a quantitative measure can be applied to these two phenomena the law may then be stated in a formula of the type $y=f\ (x)$. We may leave to one side for the sake of definiteness the functions that depend upon more than one variable. The problem then in determining an exact law is that of ascertaining the character of f.

Now when we define a function we must by the definition be able to calculate in some manner the value of the dependent variable y, for any assigned value of the independent variable x. If the independent variable can assume only a finite and in fact a relatively small number of values, then our mode of ascertaining y may be reference to a table of values giving y for each x, as for example the farmer refers to the almanac to find the time of sunrise for each day of the year. If the number of values necessary to consider becomes relatively large, though still finite, as, for instance, 10^{34}, the limitations of humanity make it impracticable to utilize a table of values to ascertain y when x is given. In this case and in the case in which there is an infinity of values of x, the values of y must be given by some kind of an expression which can be computed in at least a reasonable time.

In determining the laws of science, we find that in some cases these are worked out from a given set of observations, necessarily finite in number, and indeed relatively few. In order to determine a general formula, then, which will hold good for an infinity of cases or for a relatively large number of cases, it becomes necessary to supplement the observation with various hypotheses, or assumptions. The most common of these is the assumption of continuity, which means that if we change the value of the independent variable by a variable increment, the change in y will be a variable increment (including the case when this variable assumes equal values for all its range) and the two increments decrease together, indefinitely. That this assumption is the most natural one for the mind to make would be quite evident if we accept C. S. Peirce's analysis of mind, in which he finds the great characteristic of mind is its continuity, which, indeed, is Bergson's conclusion. In any case it seemed for a long time that if for every value of x between two given values, x_1 and x_2, y must assume every value intermediate between y_1 corresponding to x, and y_2 corresponding to x_2, then y would have to be a continuous function of x. But in the progress of mathematics Darboux invented a function which does assume between y_1 and y_2 every intermediate value and yet is discontinuous everywhere. The significance of this invention for science is that science is no longer compelled to assume continuity in order to have the property cited. It is no longer necessary to depend upon actual continuity of values, that is to say, states may change instantaneously by finite amounts and yet assume every value between two given states.

Another common assumption is that of derivative. In many investigations it is assumed that if we are concerned with the ratio of two increments which decrease together, we must substitute for the limit of the ratio a derivative. For example, it is assumed that if we divide a distance-interval of a moving point by the corresponding time-interval, giving an average velocity, that in all actual motions such a ratio must, as the intervals are decreased, have a limiting value called the instantaneous velocity. So long as all phenomena of motion were supposed to be continuous this seemed to be a necessary assumption. But we know now that such a thing as instantaneous velocity may not exist at all. For Weierstrass invented a continuous function which does not have a derivative anywhere, and since his time a great many others have been invented. There is no reason at all why change of position may not take place continuously and yet with no definable velocity anywhere, although there could be an average velocity over any interval which for a smaller interval might run up as near ∞ as we like. If we remember the fact that a point which changes its position in time may assume two given values of x, and during the moment between two given instants of time, may assume every value between x_1 and x_2, and do this discontinuously, and the fact that it may do the same thing continuously and yet with no definable velocity at each intermediate instant of time, we certainly offer the scientists a chance to accept even radical modern atomistic conceptions of matter, electricity and energy, and yet not pass outside the range of the definable function. If he were to do this, however, he would be dependent entirely upon the mathematician for the development of such laws and the study of their consequences. That the phenomena of nature do not actually take place in this way we have no right to assert. While we have deduced many laws on the hypothesis of differentiability as a basis, we must recognize that it is not a necessary hypothesis. We may assert confidently that, for example, there may be motions in which there is a change of place, a definable velocity, and yet no definable acceleration, even though there may be a field of force in which the particle moves. What becomes of Newton's second law in such case? Again the ordinary laws of dynamics are based upon the assumption that there are practically no shocks or collisions, but if we suppose that there is a relatively very large number of collisions or an infinite number, then the solutions of the actual dynamic laws would have to be functions with a relatively dense set of discontinuities, or even infinitely discontinuous functions. That such are possible every mathematician knows.

We may go still further, however. Many laws of science are the solutions of either total or partial differential equations. Now it is generally supposed that if we have the second derivative of a variable given in an equation, we may from this equation find the third derivative, then the fourth, etc., and thus for a domain not too large find the coefficients of a Taylor series for the function. That is to say more briefly we find that most functions are assumed to be analytic. Now it is well known that in a wide field of physics these analytic solutions are, even if possible, of no interest, and that we must seek for solutions which are at least nonanalytic on certain boundaries. But we can still advance owing to the investigations of Borel, for he invented a differentiable function which in no region, however small, is analytic. This function, for example, would permit us to study the potential in a region which was discontinuous at a set of points everywhere as dense as rational numbers. We do not then have to assume that if a function is continuous, and it has derivatives that it is necessarily analytic.

Turning now to another class of investigations, we find that it is generally assumed in some sciences that the succession of phenomena depend only upon those phenomena that immediately precede. Indeed, this condition permits the use of calculus. But the assumption is purely gratuitous, for it is possible to devise functions in which not only the preceding state but other preceding states act upon the present. It is as if the remote past can reach out a ghostly hand and affect the present. The bearing such a possibility has upon heredity is evident at once. And the mathematician, since Volterra devised such functions, can assert that the assumption of no action over an interval of time is simply an assumption.

A still different kind of function is also due to Volterra and others, namely the function dependent upon a whole infinity of independent variables. Usually the number of independent variables is assumed to be relatively small. The whole tendency of science is to reduce the number of causes. This may be due to the fact that functions of an infinity of variables had never been studied. But this obstacle is now removed and in the study of functions of lines, surfaces, etc., as well as various functional spaces, we have the development of a means of statement of law which may be more useful in the future than it is now, as it is extended to wider fields of science.

Time does not permit more than a mention of the far-reaching dependence upon the laws of statistical mathematics that science has immediately at hand. Problems of distribution, organized and unorganized; problems of large numbers, problems of values that are given only as averages, problems of functions that merely must keep their values within a given approximation, all these suggest that the conception even that a measurement actually has a unique value which could be determined exactly is also an assumption.

But I hear the objection raised, that the fact that the mathematician is able to amuse himself with creations of this kind is one thing, and that the laws of nature belong to their applications is another. I need only remind you, however, that conic sections were studied many centuries before Kepler lived, and that wireless telegraphy is very dependent upon the square root of minus one. This order of events does not always occur but it happens often enough to answer the objection.

In the effort to explain the universe, science is driven more and more toward the postulate that the universe is infinitely complex, and away from the postulate that the universe is comparatively simple. The intricacies of phenomena increase year by year, and the scientist, like the mathematician, is compelled to admit that to generalize merely by adding more terms is a very poor way to generalize. The generalization necessary to handle nature, like the generalization necessary to handle increasing knowledge of mathematics, is plainly a generalization of kind, that kind of generalization which will exhibit the simple case as a degenerate form of the usual case. A more profound insight into the tangle of phenomena shows that the threads are not simple and well known curves merely mixed together, but that they are in reality infinitely complex curves intertwined with themselves. That some of them from certain viewpoints project into straight lines, or circles, or simple helices, is purely an accident. Since this is the case it becomes plainly evident that progress in science is very dependent upon the creative power of the mathematician in matching intricacy in nature with intricacy in mental construction. It becomes very plain that such heavy assumptions as continuity, vicinal action, analyticity, uniqueness, determinability, and others of the same ponderous character, must be left aside, and that discontinuity, distal action, monogeneity, polydromicity, statisticity, and the like, must become the more frequent. And all these demand mathematical development which is as yet only dreamed of.

THE CORRECTION OF ECHOES AND REVERBERATION IN THE AUDITORIUM AT THE UNIVERSITY OF ILINOIS

By F. R. Watson, University of Illinois

A brief account is given herewith of an investigation of the acoustical defects of the Auditorium at the University of Illinois. This investigation has extended over a period of nearly seven years and was recently brought to a conclusion when materials were installed to correct the reverberation and echoes.[1]

The Auditorium is a large structure nearly hemispherical in shape, with several large arches and recesses which break the regularity of its inner surface. Because of its large size and concreted curved walls, it was afflicted with both a reverberation and echoes. A watch ticking on the pulpit could be heard far away in the balcony. A whisper started by an observer on the stage was returned so that it could be heard distinctly after it had traveled a distance of 225 feet. Echoes were heard from every direction and the reverberation lasted for several seconds. Speakers found their utterances thrown back at them and auditors in every part of the house had difficulty in understanding what was said.

This unfortunate condition proved beneficial in the respect that it allowed tests of faulty acoustics to be made under exceptionally good conditions. A systematic investigation, avoiding "cut-and-dry" methods of cure, was inaugurated first

[1]Detailed accounts of the investigation with numerous drawings and photographs may be obtained in Bulletins Nos. 73 and 87 on "Acoustics of Auditoriums," and "The Correction of Echoes and Reverberation in the Auditorium, University of Illinois," published by the Engineering Experiment Station of the University of Illinois. These bulletins may be obtained on application to the author or to the Director of the Engineering Experiment Station, University of Illinois, Urbana, Ill.

to ascertain what the acoustical defects were and then to investigate the methods of cure and apply them to correct the trouble.[2]

The usual acoustical faults in auditoriums, as pointed out by Professor Sabine[3] in his classical experiments on this subject, are a reverberation, or undue prolongation of sound, and echoes; both of these faults being due to reflection of sound from the walls. Sabine has shown definitely how the reverberation can be corrected by installing sound-absorbing materials. Other defects, such as interference and resonance, may also be present, but they are usually of small consequence compared with the first two mentioned.

The reverberation in the Auditorium at the University of Illinois could therefore have been cured by installing hairfelt on the walls. Experimental tests on the reverberation were conducted by Sabine's method and calculations made to determine the amount of absorbing material needed to reduce the reverberation to a satisfactory point. The greatest annoyance, however, appeared to be due to echoes, so that the main purpose of the investigation was to find the echoes and eliminate them.

If an observer stood on the stage and clapped his hands a veritable chaos of sound resulted and echoes were heard from every direction. This action was too complex to lead to a definite analysis of the trouble, so a simpler method was adopted by which a small beam of sound was to be sent successively in different directions and its paths traced after reflection. A difficulty then arose to find a suitable arrangement of apparatus to carry out the method. A ticking watch backed by a reflector gave definite data, as did also a metronome enclosed in a box so that its sound could escape only through a directed horn. The results were not entirely conclusive. A satisfactory method was finally found by using an arc light at the focus of a parabolic reflector. The arc gave forth an intense hissing sound that traveled with the light so that an observer could see where the sound struck and thus locate the walls that

[2]"Echoes in an Auditorium," Physical Review, Vol. 32, p. 231, 1911. "Air Currents and the Acoustics of Auditoriums," Engineering Record, Vol. 67, p. 265, 1913. "Acoustical Effect of Fireproofed Cotton-Flannel Sound Absorbers," Engineering News, Vol. 71, p. 261, Jan. 29, 1914.

[3]See articles on "Architectural Acoustics," American Architect, 1900.

caused the echoes. Small mirrors attached to the walls assisted in tracing the reflections.

Experiments to improve the acoustics were then carried on in accordance with the results of the analysis. Sounding boards, or more properly, reflecting boards, of various kinds were tested.[4] A flat board about five feet square was placed at an angle over the position of the speaker. This proved to be of small effect, as was also the case when a large canvas sheet 12 by 20 feet was similarly mounted, although speakers said the ease of speaking was increased when they stood under the canvas. A parabolic reflector was then tried and gave much better results, but it had several disadvantages. It was necessary for the speaker to keep closely to the focus of the parabola to have the sound proceed properly. Any movement on his part would diminish the efficiency of the reflector. Also the sound worked both ways, so that noises generated by the audience were focused at the speaker's ears. The reflector was suited only for a single speaker and would not serve for concerts or plays where the entire stage was used. Furthermore it did not reduce the reverberation materially.

A word or two should be added concerning the use of wires in correcting acoustics. Wires attached in an auditorium have practically no effect on the acoustics. Five miles of wire were installed in one church and the acoustics still remained imperfect. Wires have much the same effect on the sound that a fish line in the water has on water waves. To break up the sound, the obstacle must be much larger than a wire; it must have dimensions comparable with the wave length of the sound.[5]

Canvases were then hung in various positions in the hall to determine the effect of cutting off certain walls from the action of the sound. Absorbing materials were also hung at critical points suggested by the analysis. The final provisional cure was brought about when four large canvases were hung in the dome. For the first time speakers could talk with comparative ease without suffering great annoyance from echoes.

[4] "The Use of Sounding Boards in an Auditorium," Physical Review, Vol. 1, 2 , p. 241, 1913. Also a more complete article in The Brickbuilder, June, 1913.

[5] "Inefficiency of Wires as a Means of Curing Defective Acoustics of Auditoriums," Science, Vol. 35, p. 833, 1912.

From the acoustical standpoint the Auditorium was then in fairly satisfactory shape. The canvas curtains, however, were unsightly and did not accord with the architectural features of the room. Steps were taken to find an arrangement that would satisfy both the acoustical and architectural requirements. Calculations were made by Sabine's method to determine the amount of hairfelt necessary to cure the reverberation. Unfortunately this amount was not sufficient to cover all the walls producing echoes. It was desirable to eliminate the echoes, but it was risky to install much absorbing material and make the Auditorium too dead for sound.

In the face of this difficulty it was decided to carry on further experiments before attempting the final cure. One of the large curved walls was covered with vertical strips of hairfelt 30 inches wide placed 30 inches apart with bare wall space between them. This arrangement had several advantages. It maintained the curvature of the wall and used only half the material necessary to cover the surface completely. Also, it was theoretically more effective in breaking up the incident sound because the portions of the waves striking the felt strips were strongly absorbed and changed in phase. The results obtained were encouraging, though not as marked in diminishing the echoes as anticipated. Another wall was therefore padded in a similar way except that the felt strips were installed one foot out from the surface. This would allow the felt to act on both the incident and reflected waves and thus more thoroughly modify the regularity of the sound. The dome surface was also treated, the felt being mounted in radial strips placed 18 inches from the ceiling at the edge of the skylight and gradually nearing the wall until it touched at the crown of the arches.

Other changes were made in the Auditorium. A pipe organ was installed, the lighting system was changed and the interior was redecorated. All of these modfications affected the acoustics and were considered when calculating the amount of hairfelt to be used.

The results obtained have been generally satisfactory. The remodeled Auditorium has been used almost continuously under varied conditions for music and speaking and has been found to have acceptable acoustics. A speaker with a moderate voice can be heard and understood by auditors in the most distant seats. According to experts, the music of the pipe organ is satisfactorily rendered. The room is suited also for orchestra music, although for this case the carpet is removed from the stage so as to provide a sounding board for the instruments. The reverberation is not excessive even when no audience is present, so that rehearsals may be conducted under favorable conditions. Several instances of echoes have been reported, but these do not appear to prevent the words of the speaker being understood.

While the best evidence for the improved conditions was furnished by the favorable opinion of the auditors, it was thought desirable to get additional information by experiment. Accordingly, the time of reverberation was determined experimentally and was found to be satisfactorily reduced from what it had been before the correction was made. Echoes were tested by the arc light reflector, and by a special arrangement of megaphones. The padded walls diminished the sound to such an extent that they produced little trouble, but several unpadded walls of comparatively small area produced echoes under particular conditions. For instance, when the speaker faces such a wall so that the auditor can see the profile of his face, an echo is perceptible. This is because the sound coming directly to the auditor is diminished while that reflected from the wall is augmented.

The main conclusions of the investigation are as follows: A room with large volume and hard, nonporous walls with but little sound-absorbing materials will have a reverberation. If the dimensions of the room are great, echoes are likely to be set up, especially if the reflecting walls are curved. Walls responsible for the production of echoes may be located by using an arc light backed by a reflector as a source of sound. Such a room may have its faulty acoustics corrected by installing sound-absorbing material, but this should be placed so as to eliminate echoes as well as to reduce the reverberation.

THE FUTURE OF POPULAR SCIENCE

John C. Hessler, James Millikin University

1. *Meaning of Popular Science.*—I realize that my subject, "Popular Science," has had some unpleasant associations in the recent past, but I am tempted to use it to bring before the State Academy of Science, in the few minutes allotted me, some thoughts on the science situation in this country, especially on the teaching of science in our schools, colleges and universities. If I can suggest to you that this country may have and should have a science which is *popular,* that is, for the masses, as well as one which is *technical,* that is, for the experts, I may not be subject to the sneers of the sober man of science nor will he feel that my suggestions are, of necessity, fit only for the limbo of lost ideas.

2. *Popular Science of the Past Generation.*—The year 1890 may be taken roughly as the beginning of the laboratory period in American high schools, especially in the Central West. As we think of the two preceding decades (1870-1890), years in which men as old as the speaker, or older, probably received their first inspiration to engage in science work or teaching, we remember them as the "wonder years of science." They were "wonder years" because of the wide-mouthed, eager wonder of so many of our people for scientific discoveries. The Philadelphia Exposition, with its early telephone and arc light, the untold, apparently illimitable extent to which discovery might go, the bicycle and the prophecy, as yet so dim, of the automobile and the aeroplane, gave to the professional lecturer a profitable field. Crowds went to hear lectures by "Professor" Blank on the "Wonders of Electricity" or the "Little Devils of Chemistry." Here static machines turned rapidly with gratifying zips of electric discharge, Ruhmkorff coils hissed and buzzed, Crookes tubes fluoresced in endless play of color. Or mysterious rubber bags, with weights upon them, delivered the wonderful gases of the oxy-hydrogen flame, liquids that were red were changed, in a twinkling, to blue, and then turned back to red again by the addition of colorless water. Specks of a white powder swelled up, when ignited, to an enormous bulk, while a great, bulky amalgam shrank to a droplet of liquid mercury. And when

interest lagged there was always an explosion to make everyone start to his feet.

These and multitudes of other "experiments" came as the natural result of the discovery of the new applications of electricity and chemistry. The lectures were spectacular, often inaccurate, but nevertheless of absorbing interest and stimulation. They stirred up the imagination of a non-scientific, but inventive people; who can tell how many of the later, perfected pieces of electrical and chemical apparatus came solely, or came sooner, through their influence!

The seventies and eighties were also the age of the Chautauqua Literary and Scientific Circle. Old as well as young people, denied the advantages of college education, read the classics in English translation and studied science in the form of Professor Steele's "Fourteen Weeks" courses. The more sober went on to Popular Science Monthly and the Scientific American. As we think of that age we must conclude that relatively, if not absolutely, its interest for knowledge, such as it was, was very high; the mind, as well as the mouth, was open to receive the wonderful new ideas that were "put across" the lecture table.

3. *Results of This Interest.*—The thesis I wish to present, and can hardly more than state, is this, that in my belief this interest largely created by popular lectures, text books, magazines, and science study circles, is responsible for the rapid development of laboratories in our high schools and many colleges and for their present magnificent buildings and equipment. We school men are often likely to find fault with the niggardliness and shortsightedness of the public in certain special cases in which we are interested, but we need to remind ourselves again and again that there has been a tremendous loosening up of purse strings in the last twenty or twenty-five years, especially with regard to school outfitting. Here, in the presence of this new chemical laboratory (that of the University of Illinois), is it necessary to suggest that the same is true of the university? We need not be old to remember the days when such things would have been utterly impossible, even if we had had our present great national wealth.

I remember well the case of a new high school building in Chicago, first occupied in 1887, and situated in the center of one of the most thickly settled portions of the city. The leading newspaper of the city attacked the Board of Education most viciously because the board had expended the enormous sum of, perhaps, $175,000 on the building. The building had not a single laboratory for the pupils' use, as I recall matters. In contrast with this case is that of a high school I visited the other day, in a city of less than 90,000, in which the science *addition* to the building cost $180,000. My point is that much of this change of sentiment is due to the popular science courses of a few years ago and to the conviction produced in the minds of people who themselves had no opportunity to study in the laboratory, that laboratory experimentation was worth while.

4. *Relation of the People to Laboratory Science.*—In a country having a strong governing class the people may permit experts to tell them not only *how* they should spend their money, but how much they should spend; not so in this country, if we can judge by the signs. Here the common man will still have something to say regarding the how much, however far he may ultimately defer to the expert with regard to the use of money. For some years, even without any popularization of science, the appropriation for science laboratories will continue from its own inertia. But sooner or later the Philistine will have his day.

The theory of the laboratory as a part of a school's equipment was that all of the people should have an opportunity to experiment for themselves and thus to get the benefit of first-hand acquaintance with nature. Some qualifications of this theory are in vogue today. I have had considerable opportunity, in the past few months, to observe high school science teaching, to say nothing of college and university teaching. In both classes of institutions I have heard teachers state again and again their belief that the benefits of laboratory work were greatly overrated, that pupils work blindly to get results, while to many instructors the laboratory note book seems to be the principal object of the course. These teachers believe what they say is true, and all of us who teach have probably some share in the belief. Now, I wish to suggest that this is the very antithesis of the belief expressed more or less forcibly by teachers of a generation ago, who held that about all that was needed for the millenium was to let everybo ly experiment.

If an upsetting of our theory were all that is involved in this new conception of the laboratory, we might dismiss the subject with a smile for the impracticability of our youthful beliefs. But this is not all. When once the man who runs gets hold of this gossip of the science teachers, he will run in another direction. The motive for the most expensive part of school and college buildings—I mean the science laboratory—will be gone and he will act upon his new knowledge to vote no more such expenditures.

5. *The Future of Popular Science.*—For what I have stated, you will see that I believe a future is desirable for popular science. Shall there be one, more significant than anything of the past? Or shall it be, like the traditional apple in the hands of the small boy, without a core? Is it worth while for men of science, such as those of the Academy, to seek by more worthy methods to appeal to the wonder instinct of the people? Or is a people that knows the movies and the cabarets lost to the possibility of wonder? I believe that by giving the people something it can understand in the newer terms of a more sound science we can make, if we will, a better partnership between the investigator and the public. We can use the movies themselves. Each member of such academies as ours can serve as the apostle to his own community. By lectures or by simple courses of study, not too long, the interest of the people may be stimulated and they may be given something worth while. Suppose we were to copy from the schools of agriculture a few lessons and that we were to distribute to the constituents of our schools pamphlets beginning something like this:

"Your children are receiving at school the vocabulary of modern science. This vocabulary is not an end in itself, but the means of further education from science texts, newspapers and government publications. If you desire it, the men of science of Illinois will give you, too, this vocabulary in an understandable form. They believe that by informing yourself more fully you will be able better to judge the needs of science and will be able to make of your state a better place for yourselves and for your children."

Is there anything in all this that is antagonistic to investigative science? To use an illustration borrowed from the laboratory, if we wish to get the pure crystals of blue vitriol out of the dirty, unpromising lump of bluestone, we dissolve it in water and manipulate the solution so that crystallization begins. But when the beautiful crystal appears, shall it say to the turbid mother liquor, "I have no need of you?" The solution is old-time "popular science"; the beautiful crystals are the fruits of investigation. As I see matters, the scientific progress of our democracy must ever be dependent upon an understanding on the part of the people of what its experts are about and upon the willingness of the people to trust these experts in the fields into which the people as a whole cannot enter. In other words, science and confidence must be the real food of our national life.

THE HOSPITAL AND ITS FIELD OF WORK FOR THE GENERAL SCIENTIST

Walter G. Bain, A.B., M.D., St. John's Hospital
Springfield

As late as 1890 the preparation for the practice of medicine was limited to two years of college lectures. The medical student made during these two years a careful study of anatomy. He studied chemistry a very little, physiology a very little, physics, bacteriology and biology not at all. The greater part of the student's time was devoted to listening to lectures on medicine and practice, wherein the experienced practitioner described as great a variety of diseases as his experience had enabled him to observe. With the information acquired in these two years the doctor went out to begin his practice. In those days the old physician was the most reliable because experience had taught him at the expense of his patients.

It was about this time that the science of chemistry, bacteriology, physics and physiology began to play a part in the education of the doctor. By the application of these sciences, to which more recently has been added the science of biology, the practice of medicine was placed on a scientific basis. The hundreds of isolated facts which had previously been the bulk of knowledge acquired by the medical student were now classified and grouped and shown to conform to certain principles of general scientific knowledge. The acquiring of a medical education then began to be the learning of the general scientific principles which underlie the knowledge of matter and its relation to life.

The importance of a knowledge of the sciences has become so great that the medical student must now spend some eight or ten years in preparation instead of the two years which was considered sufficient in earlier days. This time spent is barely sufficient to give the medical student a general knowledge of sciences allied with the practice of medicine. Hardly has he received his diploma and entered into practice when he finds that he must possess more than the general knowledge of science, that he must possess a technical knowledge of chemistry, bacteriology, physics, histology and biology if he is going to advance. This means further years of study and also means that he must be especially adapted to technical work.

He has one alternative, that is to associate himself with one or more persons who have this technical knowledge, and who will apply it for him on cases upon which he is making a study of disease. This association is being forced on the physician. The field of work for the associate of the physician is important even today, and I believe my statistics show that it will be constantly increasing until the practice of medicine will demand intimate association with the general scientists, to whom we medical men are so much indebted for the present advance of our medical knowledge.

To show the exact relation of these scientific workers to the science of medicine, I have arranged a chart which covers in a general way the necessary classifications one must observe in the diagnosis and management of disease.

This classification for diagnosis and treatment of diseases of the body is based on the embryological formations of the different systems in order as they occur in utero. The classification of facts which lead to definite information as to diseases of one or more of these systems I have placed in an arrangement which in my work I have found most natural and desirable, placing the subjective information first, next information elicited by so-called clinical examinations, next information elicited by laboratory tests, fourth the grouping of the pathological findings according to one's knowledge of the diseases of the separate systems, then the conclusions, and lastly the treatment as indicated by the information acquired.

Referring to the third column in Chart I, under laboratory findings one gets a general idea of the part in the science of medicine to be played by the general scientist. To the man in practice this part of his work has reached a state of progress where it is of so much importance that the larger hospitals have already equipped, and the smaller hospitals will soon find it necessary to equip a special department.

We have such a department equipped at St. John's Hospital in Springfield, Illinois, the general plan of which is shown in Chart II. In this chart I have endeavored to show graphically the relation of the physician and surgeon to the work of the technician trained in sciences. As you see, the greater proportion of this work can easily be done by one having knowledge of the science independent of a medical education. Thus the management of the X-Ray department requires a knowledge of physics, anatomy and electricity, and I believe a person whose interests are centered in these sciences will do more to advance our knowledge of roentgenology than ever will the general practitioner himself.

In a clinical laboratory we need a bacteriologist, a chemist and a biologist. It is facts and information acquired by specialists in these branches that the man in practice must have in his diagnosis, and for lack of time and technical training cannot obtain. It is therefore to these scientists that we must look for help in acquiring this information in the future.

To show you more in detail the importance of this, and the amount of work that can be done and is being done, I have arranged a third chart in which the principal procedures are classified and the number of specific tests are recorded in relation to the number of patients. In Chart III the line A.A. illustrates the indications for the principal laboratory procedures as we have worked them out on a series of 250 carefully studied cases. The line C.C. shows requests for these examinations in a series of 8,000 cases as they were entered in our institution during 1913 and 1914. The line B.B. shows the increased demand for this work as illustrated by data from 4,500 cases entered during 1915. Whereas in our laboratory in 1915, 6,349 examinations were made, 40,000 examinations would have been made had the cases entered been studied as carefully as indicated in the selected 250 cases.

As to the financial returns for this work, suffice it to say that our records show that this work can be carried on and be made self-supporting.

In the larger institutions at the present time there is room for two or three men who can profitably devote their entire time to this class of scientific work. In smaller institutions at least one person can find a field of work in the hospital. In our smaller towns where a hospital is not available our teachers of physics, chemistry and physiology can find a field both profitable and educational by associationg themselves with one or more of the practitioners in their community. If any of you should doubt these statements, in proof of the demand for this class of workers I have only to refer you to the "Want Column" of the medical publications.

In conclusion, I would like to thank Dr. Albert R. Trapp, who has been associated with me in the study of the 250 special cases mentioned, and in the work of making the classifications and outlines presented.

CHART I
INDEX OF PATHOLOGY

Date ——————

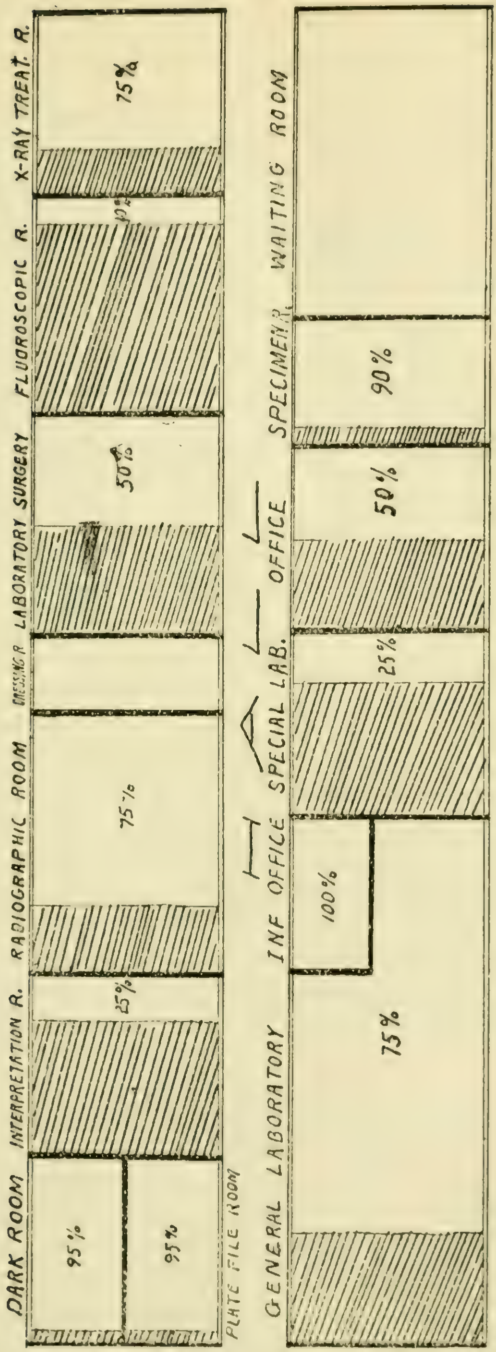
Case No. ——————

Attending Physician ——————

Patient's Name ——————

System Involved	Information from Patient							Data from Clinical Examination								Laboratory Findings													Symptomatic Group Relations	Conclusions	Treatment
	Family History	Personal History	Infect. Disease	Organic Disease	Funtional Dis.	Present Trouble		Inspection	Palpation	Percussion	Auscultation	Instrumentation	Mensuration	Reflexes		Blood Analysis	Wassermann	Blood Press.	Polygraph	Gastric Secre.	Feces	Urine	Sputum	Exudates	Tuberculin	Temperature	Elec. Reaction	X-ray			
Vascular																															
Digestive																															
Nervous																															
Special S. Org.																															
Respiratory																															
Skin																															
Muscular																															
Genito-Urinary																															
Skeleton and Limbs																															
Unclassified																															

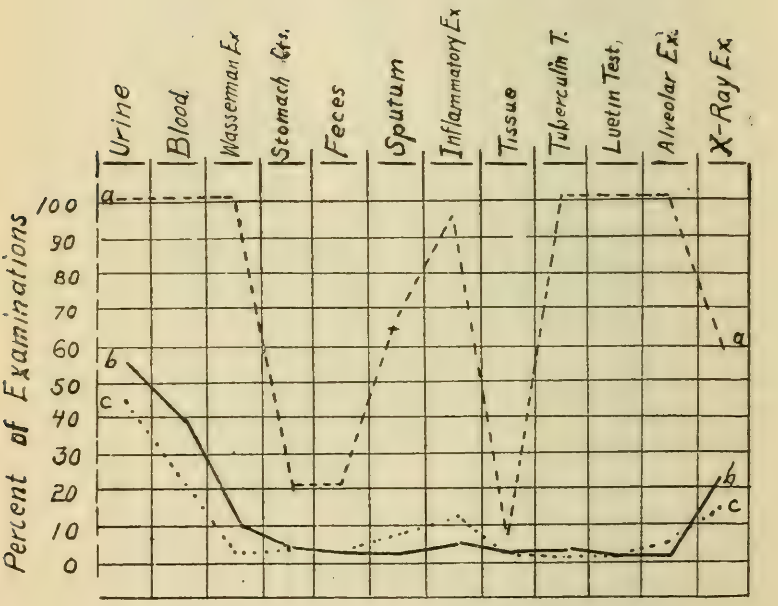
CHART II



Percentage of responsibility to be assumed by person with training in medicine and surgery.

Percentage of responsibility to be assumed by person trained in chemistry, bacteriology, physics, etc.; nurse or clerk.

CHART III



a,a, percent of examinations in properly studied cases based on records of 250 cases; b,b, in 4500 cases entered in the hospital 1915; c,c, in 8000 cases entered 1913 and 1914

DISCUSSION OF DR. BAIN'S PAPER

Dr. A. R. Trapp, Springfield

Mr. Chairman and Members of the Academy:

I wish to discuss Dr. Bain's paper from the viewpoint of a physician. For the last sixteen years I have been engaged in the practice of medicine. And for the past five years it has been my good fortune to have been associated with Dr. Bain in this work. Now in order to examine a person, thoroughly, it is necessary to employ all of these scientific tests, to do which would require ten to twelve hours of one man's time. This would limit a physician to one patient per day, or else he would have to guess at the patient's ailment. And one who guesses is not a whit better than the quack. So you can readily see what the profession is up against.

Now Dr. Bain has offered the solution of the problem, and that is for the physician to surround himself with a group of scientifically trained associates, this group of workers constituting, if I may borrow a term used by our engineering colleagues, a unit power plant. I have seen this plan carried out in the examination of 250 persons and I assure you it has been successful even beyond our expectations. Allow me to cite an example: A few weeks ago there walked into my office a gentleman for such an examination. He had recently been examined and accepted by an old line life insurance company, he was not feeling ill and did not come of his own volition but at the request of a friend, a man who was a scientist and who had become aware of the value of Dr. Bain's work.

This examination showed serious defect of the cardio-vascular system, viz., while the maximum blood pressure of 140 was within normal limits, his minimum was lower than his pulse pressure, a condition which is pathological; his hæmoglobin (color) of the blood was lowered as well as the number of red blood corpuscles, which was less than 3,000,000 per c.c. when they should have been 5,000,000, which is the normal number The blood further gave a positive Wasserman reaction, a test which shows the presence of syphilis. The X-ray showed besides an enlargement of the heart, an infiltration about the right lung and the gall bladder. The urinary findings were those of an incipient Bright's disease. And this man had been passed and examined by a competent physician!

A successful merchant takes an invoice yearly and thereby knows how his business stands and to know if he shall assume new risks, but he never once thinks of invoicing his own physical condition. Let me tell you were this done oftener we should not be so frequently shocked when we pick up the morning paper to read of the sudden death of some prominent merchant or world's statesman. More of such lives would be prolonged and their families and their country would be the richer. The medical profession of Springfield is beginning to realize the value of Dr. Bain's work and the laity, too, are coming to appreciate his work and I assure you it will not be long until Dr. Bain is given the honor and credit due him.

DISCUSSION OF DR. BAIN'S PAPER

T. J. Burrill, University of Illinois

Mr. President:

I have been much interested in the presentation of the subject by Dr. Bain and wish to express, too, my high estimate of the importance of the subject itself. Every one of us, whether supposedly well or sick, needs this occasional invoice taken of our bodily condition and needs more fully wake up to the fact that prevention is better than cure, though both are concerned here.

Let me especially apply my remarks to the local situation, to the university within whose walls we are assembled, with some 500 names in the faculty list and 5,000 in the catalogue of students. Each one of these people, engaged in the betterment of human life, needs above everything else for his work full physical and mental health, and for this each is greatly dependent on the condition in this respect of his associates. Each is vitally concerned as to the question of health or disease of his neighbor, his fellow collegian. Yet until the beginning of the present year, it may just as well be said, there has never been any general, systematic examination whereby existing facts in this relation could be known or provisions to meet them made.

Since it is impossible to elaborate here I will cite one case the better to illustrate what is in my mind. Some ten or twelve years ago a young man of athletic build and apparently in vigorous health was doing the work of a class in bacteriology, and when the subject of identifying the organism of tuberculosis came up he, as a matter of curiosity and none other, prepared material which he managed to cough up himself. To his astonishment and that of others there was unmistakably the dreaded bacillus. This was in March of his senior year. From that time on he did everything believed to be helpful for one so infected, but in June of the same year a diploma was conferred upon him while he was in the hospital under the most vigilant attention of a physician and nurse owing to an entirely unlooked for hemorrhage from the lungs. But from this last he soon recovered and then devoted himself sensibly to the recovery of his health. He is today a strong, effective and honored member of the faculty of an agricultural college in a neighboring state instead of what he might have been, a suffering and slowly doomed man and a menace for some years to those nearest and dearest to him. And this difference came about by that early accidental discovery. How many were there at this same time in similar condition whom mere fortune did not so favor?

I am exceedingly glad to be able to report that beginning with the present year the happy-go-lucky state of things has been changed to rational examination and authoritative procedure.

But such facilities as Dr. Bain describes should be available in every community and the absolute necessity of such examinations should be thoroughly and widely appreciated, as the best practicing physicians do appreciate the aid thus afforded.

THE AVOIDABLE LOSS OF LIFE

J. Howard Beard, M. D., University of Illinois

As a nation, we are moved to immediate action by the loss of a few hundred lives in a spectacular way, but the deaths of thousands of our fellow citizens from avoidable, but insidious causes, do not interest us in proportion to the loss involved or stimulate us to the necessary efforts of prevention.

The burning of a theater with the loss of several hundred lives is reported as a disaster and is followed by legislation making public buildings safe, but whooping cough, which destroys annually 10,000 persons and renders 190,000 ill, is frequently not listed as a notifiable infectious disease. We are horrified at the European conflict, but the combined loss of all the navies engaged is less than the number slain each year in this country by the typhoid bacillus. In a modern battle 100,000 men may be killed and wounded, but the tubercle bacillus slaughters 147,600 of our citizens yearly, and a million and a half remain infected, the greater number of whom will die of tuberculosis.

COMMUNICABLE DISEASE

Over 500,000 people die of communicable disease each year in the United States and over five millions are sick as a result of infection. Had such a loss of life and health been localized, a city the size of Cleveland would have been depopulated and every individual in two cities the size of Chicago would have been in need of medical attention.

The immediate death rate and illness of infectious diseases are scarcely more important than those of their complications and sequelae. Measles and whooping cough prepare the soil for tuberculosis; scarlet fever for renal diseases; rheumatic fever, tonsillitis, pneumonia and syphilis for cardiac failure; and, infectious disease, in general, and syphilis in particular, for vascular degeneration. The effect of sequelae are well illustrated in the recent studies of Dublin in connection with typhoid fever. He noted that the death rate among typhoid survivors for the three years following the attack was twice the expected mortality for an equal number of individuals of the same age, sex and color. Of those dying within three years following recovery, tuberculosis caused 39 per cent of the deaths and heart disease 14.8 per cent. Dublin estimates that 8,000 deaths occur in the United States each year among persons who have had their vitality so impaired by typhoid fever that they succumb within the first or second year after recovery.

Twelve thousand persons die of measles in the United States annually, and ten thousand of whooping cough. Eighty-one per cent of the deaths due to measles and 95 per cent of those caused by whooping cough occur in children under 5 years of age. The failure of the mortality rates of measles and whooping cough to show a reduction during the last fifteen years is due to the fact that they are highly communicable in their early stage, when diagnosis is most difficult and to the attitude of the public, which regard their presence as to be expected and of little consequence to either the individual or to the community.

Scarlet fever causes the loss of nearly nine thousand lives, 82 per cent occurring before the tenth year of life. Scarlatina is difficult to control, as its cause is unknown and mild cases may occur which are almost impossible of detection, but which serve as a focus for further spread of the disease. It is certain, however, that many unnecessary cases of scarlet fever are due to lack of care of the attendants upon patients; the non-pasteurization of milk; the failure to give thorough disinfection; the absence of adequate medical inspection of schools; and to imperfect isolation and too short quarantine. The deaths due to the failure to use effectively the well-recognized methods of prevention could and should be avoided.

Diphtheria and croup are responsible for the death of 18,000 people annually; 88 per cent within the first decade of life. The fatal cases of croup are usually the work of diphtheria bacillus. The number of deaths due to diphtheria have almost uninterruptedly decreased during the last fifteen years and, at present, are less than one-half that of 1900. As striking as this decrease may be, the mortality is much too high for a disease of known etiology, of well-recognized epidemiology, and one for which we possess a specific preventive and curative therapy.

The mortality of diphtheria is almost entirely dependent upon the time of the administration of the antitoxin. If it is given in sufficient dose within the first twenty-four hours, practically all patients will recover; if withheld beyond the first day, the death rate increases with each hour. The delay in receiving antitoxin is usually due to the slowness of the patient to obtain medical attention and the waiting on the part of the physician to determine the nature of a suspicious sore throat clinically, rather than bacteriologically.

In 1913, there were about 18,000 deaths from typhoid fever and approximately 180,000 cases. Happily, this is a reduction of 50 per cent in twelve years, but the rate is still inexcusably high. Typhoid fever so impairs the vitality of the individual that his mortality is twice the expected death rate during the three years succeeding the attack and in this way, according to Dublin, is responsible indirectly for the loss of 8,000 lives annually.

Typhoid fever should be eliminated. Improvements in water supplies, scientific sewage disposal, the protection of milk, meat and vegetables from contamination, the anti-fly campaign, and, perhaps, the adoption of typhoid inoculation, have been largely instrumental in lowering the death rate from 35.9 per 100,000 population in 1909 to 17.9 in 1913.

The contact of a large number of individuals aids in the dissemination of typhoid fever, yet the death rates of our largest cities, which take precautions against the typhoid bacillus, are about one-third the rate of the entire registration area. While certain large cities have shown great progress in the reduction of typhoid fever, the sanitation of the rural section of the country is in its infancy and in many of the smaller towns and villages the insanitary privy and polluted well are menaces to the health of the community.

It is impossible to determine the extent of syphilis, a disease protean in its manifestations, variable in its intensity, chronic in its tendency, and hereditary in its scope. It may be conservatively estimated that there are at least a million and a half syphilitics in the United States. In 1913 syphilis was directly responsible for 7,200 deaths, for 6,900 due to paresis and 2,600 caused by locomotor ataxia. It attacks the vascular system with special severity and is a great factor in the mortality due to insufficiency of the aortic valves, aneurism, arterio-sclerosis, certain groups of cases of angina pectoris, and cerebral hemorrhage. Syphilis produces over 26 per cent of still births and holds an important place as a cause of death within the first year of life. Nearly 20 per cent of the first entrances to the institutions for the insane are due to this disease. There is an increased mortality rate among syphilitics of 70 per cent, which means a reduction of the average expectancy of life by five and a half years.

In the presence of the ravages of this scourge of the human race, the one thing that stands out most conspicuously is the ability to prevent it. The moralist would attack the problem of syphilis by clean living, the abolition of prostitution, by instruction of the youth in regard to the danger of venereal disease and would discourage the postponement of marriage. These measures would be the happiest, the most efficient and certainly the most desirable means of prevention, but, on account of the frailty of human nature and the strength of the sexual instinct, are most difficult of general application. The sanitarian would utilize the full force of ethics, but, in addition, would urge the establishment of hospitals for the early diagnosis and prompt treatment of syphilis, would educate the public in the means of prophylaxis, and would make it a criminal offense for one individual to knowingly transmit the disease to another.

Pneumonia destroys annually 132,400 lives, is the most prevalent and most fatal of all the acute communicable diseases. Its occurrence has shown considerable reduction during the last thirteen years, falling from 180.5 deaths per 100,000 population in 1900 to 132.4 in 1913.

It occurs as a primary disease; as a secondary to measles, scarlet fever, whooping cough, diphtheria, influenza, and typhoid; at both extremes of life—causing the death of young children and enabling elderly sufferers to easily exchange a life of invalidism for a peaceful grave.

Pneumonia is caused most frequently by the pneumococcus, but it also may be due to other organisms. It was commonly believed that pneumonia was an autogenic infection, for a pneumococcus was to be found in the oral and respiratory passages of a large proportion of healthy individuals, and that the lowering of the vitality by exposure to cold, by inhalation of dust and fumes, alcoholism, injury to lung tissue, or senility so disturbed the balance between the virulence of the organism and the susceptiblity of the individual as to present a favorable opportunity for development of the disease. This conception does not agree with recent observations, which seem to indicate that the disease is due to contact with patients or with healthy carriers.

The prevention of pneumonia requires isolation of the patient, disinfection of his expectoration, and the avoidance of all things which tend to lower the vitality of the individual or to favor the spread of the disease by carriers. The increased opportunity for infection in cities owing to crowding demands the allaying of dust, and adequate ventilation of theaters, schools, cars and public buildings. Occupations requiring excessive fatigue, exposure to unsuitable temperatures, and to dust or fumes should be under the supervision of a sanitarian and so modified as not only to add to the efficiency of the worker, but to afford him an opportunity to increase his resistance to disease. The occurrence of pneumonia may be reduced, individual susceptibility decreased, and the devitalizing influence of modern life successfully overcome by proper exercise, the abundance of fresh air at night, as well as during the day, sunlight, sensible clothing, sufficient and suitable food, cold baths, enough sleep, attention to oral hygiene and by the avoidance of exposure, excessive fatigue and alcohol.

Tuberculosis caused 147,000 deaths in 1913. The mortality rate of tuberculosis has markedly declined, falling from 326.2 per 100,000 population in 1880 to 147.6 in 1913. The decrease has been uninterrupted since 1904. There are approximately a million and a half individuals suffering from tuberculosis in the United States.

The medical profession and the public have more consistently endeavored to prevent tuberculosis than probably any communicable disease, but, in spite of their efforts, it is of the first importance among the causes of death and is still "The Great White Plague," the captain of the hosts of death.

Tuberculosis is the unfortunate result of the combination of the tubercle bacillus and a lowered vitality. The necropsy findings and the Von Pirquet cutaneous reaction show that few persons pass through life without being infected. The failure of more individuals to have symptoms of the disease is due to their resistance and the number of bacilli taken into the body at one time.

The prevention of tuberculosis begins at birth and is a two-fold problem—avoiding infection and increasing the resistance of the individual.

Infection may be avoided by providing sanatoria for segregation and treatment of the tuberculous, the protection of the milk supply by testing of the cattle or by pasteurization, anti-spitting regulations, proper disposal of the sputum, and education of the public. Early diagnosis is of the utmost importance, for the sooner the disease is discovered, the greater the chance for successful treatment and the earlier the opportunity for the protection of others. With proper education of the public, it will be practical to make a diagnosis of "a fertile soil for tuberculosis" before unmistakable symptoms are present and without causing the individual or his friends unnecessary distress. In a person underweight, "a little run down," a poor eater, "rather nervous" and easily fatigued, the stage is set for tuberculosis. In such an individual, the time for rest, better food, fresh air and change of environment has arrived. The moment for rescue is before the rapids are reached, not when the passage of the precipice is inevitable.

The increase of resistance to tuberculosis is economic and sociologic. Good food, fresh air, sanitary houses and places of occupation, sufficient sleep and the avoidance of overwork and overworry, the essentials of a normal existence, are obtainable for the well-to-do, but not for the poor. Tuberculosis is an ally of want and squalor, and is becoming more and more the disease of the overcrowded, the underfed, and the overworked. Until social and economic conditions make it possible for each individual to have enough sleep, abundance of clean, fresh air, sanitary housing, sufficient rest and proper food for growth and energy, society may expect to reap a harvest of tuberculosis.

INFANTILE DIARRHEA

There are 75,200 deaths, annually, due to diarrhea in children under 2 years of age, a mortality exceeding the sum of the death caused by measles, scarlet fever, whooping cough, diphtheria and typhoid fever by 6,000.

This loss of life is mainly preventable. It is due to summer heat, want of care, ignorant feeding, improper food and bad hygiene. Many of these deaths would be avoided if maternal feeding was more common. Holt has shown that the death rate of the artificially fed infant to the breast nourished is in the ratio of 32 to 1. Maternal feeding requires little effort or care; artificial feeding demands intelligence, judgment and the means for the purchase of the proper food. Artificial feeding *per se* is not to blame, but ignorant feeding, the giving of contaminated or improper food or the failure to modify the quality and quantity of clean wholesome food to the needs of each child.

Heat seems to bear a direct relation to the occurrence of "summer diarrhea." It affords a better opportunity for the growth of bacteria in the child's food and for an increase of the normal flora of the intestine. It may so influence normal digestion and metabolism as to lead to the formation of toxic substances which may cause diarrhea.

Enteritis may be largely prevented by maternal feeding. The distribution of clean milk and the instruction of the mother in its modification to meet the special needs of her child, will do much to reduce the incidence of diarrhea. Strict attention should be given to the cleanliness of the nursing bottles, nipples and to the hygiene of the baby. The clothing of the child should be determined by the temperature rather than by tradition. Congested living quarters should be avoided and the infant should be kept out of doors as much as possible. The months of July and August should be spent in the country; if this is not feasible, the child should have the full benefit of the parks.

THE DEGENERATIVE DISEASES

Deaths due to lesions of the heart, kidneys and blood vessels, the diseases of old age, are on the increase. They are becoming more frequent before fifty and many individuals are dying prematurely, at an age when, as a result of training and experience, they should be most productive and of the greatest value to society.

In 1913 there were over three hundred thousand deaths due to diseases of the kidneys, heart, and blood vessels. 24.2 per cent of all the deaths due to Bright's disease and 21 per cent of those caused by organic heart trouble occurred in individuals under fifty years of age. Cerebral hemorrhage and arteriosclerosis have increased during the last ten years.

The strenuousness of modern life, the intemperance of food and drink, exposure, and the intoxications of occupation play a part in the production of renal, cardiac, and vascular degeneration. In many cases, however, we see the hand of syphilis, the sequel of rheumatic fever, tonsillitis, chorea, and of pneumonia, or the probable latent injuries of scarlet fever, diphtheria, typhoid, or malaria.

In the acute cases of kidney, heart, or vascular disease, the virulence of the invading organism, the reduction of the resistance of the individual, or both, so favor the spread of the infection that signs of disease are early apparent. In the chronic cases the injuries may be comparatively latent, the symptoms slight or absent, yet the organs may be so damaged that under the stress of modern life their period of activity may fall short ten or twenty years.

On the basis of the last statistics, there are 78,900 deaths due to cancer annually in the United States. The mortality rate has steadily increased from 63 per 100,000 population in 1900 to 78.9 in 1913. Do these figures represent an actual increase? Statisticians and notably Hoffman believe that the mortality rates "unconditionally confirm the conclusion that cancer is relatively on the increase throughout the civilized world and the increase is affecting practically all important organs and parts of the body." Physicians and surgeons are somewhat skeptical and are inclined to attribute the increase largely to better methods of diagnosis of internal cancer and to the lengthening of the average life which increases the number of individuals reaching the cancer age.

The two great predisposing causes of cancer are age and irritation. Cancer usually occurs after forty, but it may not uncommonly appear earlier in life. Any source of irritation, be it mechanical as the effect of a jagged tooth on the cheek or tongue; actinic, as the action of the Roentgen or ultra-violet rays upon the skin; thermic, as the effect of a hot pipe stem upon the tongue or lip; or chemic, as the action of arsenic and aniline dyes upon the skin, predisposes to cancer.

The prevention of cancer depends upon the education of the public as to the dangers of chronic irritation, as to the importance of the early symptoms and the necessity of an early operation. It should be universally known that any lump in the breast or unusual bleeding from the uterus in a woman above thirty-five requires investigation to exclude cancer. Sores, warts, and swellings of the lips or tongue in an individual over forty should be brought immediately to the surgeon for diagnosis. Bleeding from the bowels of a person of similar age demands the exclusion of cancer. Warts or moles that begin to show signs of growth or soreness should be removed at once. Suspicious growths should be given expert microscopical examination. All the precautions used against external precancerous lesions should be taken to avoid and discover beginning internal cancer. The best way to make a curable cancer hopeless is to delay operation or to use plasters and salves.

ECONOMIC IMPORTANCE OF PREVENTABLE DISEASE

Society is demanding each year greater skill and increased efficiency of its members, a requirement that calls for a larger investment in the training of the individual and a condition that makes the economic loss due to preventable disease most appalling. So many factors contribute to this waste that it is practically impossible to state it in figures.

Nine-tenths of all children dying of measles, whooping cough, scarlet fever and diphtheria, and all those dying of diarrhea, or any disease, before the tenth year, represent a total loss, for economic values have been created and destroyed without giving return.

The toll of syphilis, typhoid fever, and tuberculosis, is heaviest during the period of greatest usefulness. The ravages of syphilis are large between thirty and forty-five, but greatest between forty-five and sixty. It shortens the expectancy of life 5.5 years; it renders the individual inefficient during the most productive period of life; it fastens itself upon the posterity of its victim; increasing degeneracy, encouraging poverty and promoting public charges; it erects about 20 per cent of our insane asylums and taxes the nation for their maintenance. Typhoid fever causes 94 per cent of its mortality before the sixtieth year, over 48 per cent before the twenty-fifth year, and 29 per cent between the fifteenth and twenty-fifth year. Tuberculosis destroys 90 per cent of its victims before sixty; 30 per cent before twenty-five, and 19 per cent between the fifteenth and twenty-fifth year. Tuberculosis and typhoid fever not only cause over 90 per cent of their mortality before sixty, but they cause tens of thousands to seek public charity or to spend large sums to recover their health, when they should be producing. Nearly one-third of the deaths due to typhoid and one fifth of those caused by tuberculosis occur in the high-school-university period of life, the time representing the maximum investment of society in the preparing of the individual for usefulness.

Diseases of the heart, kidney and blood vessels are becoming more frequent, thus individuals are prematurely lost to society who by training and experience should be of the greatest value.

The great economic loss due to the deaths of individuals before they have become an earning power and of persons dying during the most productive period of life is relatively small as compared with the enormous loss caused by illness with its consequent loss of time of the wage earner, the inefficiency of the worker, the expenditures for medicine and attention and the absence or decrease of productiveness on the part of other individuals who must spend a part of their entire time in caring for the sick.

It is obvious that this large loss of life and health constitutes a serious curtailment of the productive efficiency of the nation and that a heavy economic burden results from the support of invalids, defectives and those deprived of their bread winners. As long as preventable diseases are present we are paying large premiums to keep them, for it would be much cheaper to prevent than to have them.

PROPHYLAXIS

Preventable disease is associated inseparably with poverty and ignorance, and any successful attempt at prevention must be an attack upon these twin brothers of human misery.

Poverty may be the great predisposing cause of disease or the result of it. Poverty by underfeeding, overworking, and poorly housing renders the individual more susceptible to disease; by overcrowding presents a favorable opportunity for the spread of infection. The English Royal Commission on Poverty states that 55-60 per cent of the poverty of Great Britain is due to sickness. The report of the Charity Organization of New York City shows about the same per cent for New York City.

The poverty-stricken individual is a fourfold menace to the nation—a poor progenitor, an inefficient producer, a potential source of disease, and frequently a malcontent. Society should realize that every individual who makes his best efforts and every child born to the nation must be guaranteed as their inalienable rights sufficient food for growth and energy, the necessary amount of sleep and rest, abundance of fresh air, sanitary quarters, and an opportunity for an education. A different attitude fails to promote the general welfare, procreates weaklings, invites disease and undermines the stability of the nation.

Ignorance can be removed only by education, and if the intelligent individuals of every community who realize the serious importance of disease to the nation are to be interested and increased in numbers until they will demand preventive machinery commensurate with scientific knowledge and the enactment of laws founded upon the present development of preventive medicine, public education must be pushed with greater vigor.

Much has been accomplished by popular literature, lectures, and demonstrations, more will be done by them in the future, but the importance of preventable disease upon the social and economic conditions of the nation demands more than an occasional public lecture, pamphlets at infrequent intervals or casual demonstrations. Instruction in the methods of preventing disease should be an essential part of our system of education and no individual should have completed his education without the knowledge of how communicable diseases are spread and prevented; the dangers of and the methods of avoiding industrial disease; how to care for an infant, and a practical understanding of sanitation and hygiene. A system of education that requires large sums of money to teach individuals English and science and does not instruct them how to protect themselves from preventable death and illness fails to insure its investment and may be criticised as incomplete.

Each county should have a full-time health officer and community nurses to meet the needs of the population. Their duties should be threefold; the control of disease, the education of the public, and as expert consultants for the citizens of the county upon matters of hygiene and sanitation.

With such a force it would be possible to make a sanitary survey of each industrial plant, place of amusement, summer resort and residence. Such a survey would reach a large number of persons who are not likely to hear public lectures or to read popular literature. A visit and a tactful conference of the health officer and property owner have not only a sanitary and educational value, but they create a sympathetic understanding between the citizen and the sanitarian, a condition essential to the practical progress of sanitary science.

Every large industrial plant should carefully supervise the physical condition of its employees, for the health of the workman determines his daily efficiency and the period of his productivity. Periodic physical examination of all employees would detect disease in its incipiency; would contribute largely to community health, and would make it possible to adapt the work to the physical condition of the worker. There would be an economic gain to the employer by the reduction of the number of accidents to workmen, material and machinery; in protection against unjust claims for compensation; in the increased efficiency of the worker, and in the decreased loss of time from preventable sickness.

The prevention of disease is the function of science and society. Science must provide the way; society must use the means and bear the cost. The acceptance by society of Jenner's demonstration of the advantage of vaccination ended the devastation of smallpox; with the practical application of the discoveries of Laveran and Ross, malaria ceased to be the scourge of mankind; the use of the knowledge of Reed, Carroll and Lazear made the Panama Canal a possibility and closed our ports to yellow fever; our understanding of the life history of the Koch vibrio has kept Asiatic cholera beyond our shores, and a scientific attack upon plague has prevented its spread and practically driven it from the country.

The knowledge of tuberculosis is as complete as that of plague; the epidemiologoy of typhoid fever and cholera are practically identical; the understanding of syphilis is as clear as that of malaria, and the information concerning diphtheria as definite as that of yellow fever. The way for the great reduction or elimination of preventable disease is known; the need is for society to educate its members, use the methods, and bear the cost.

THE UNITED STATES PHARMACOPOEIA IN ITS RELATION TO THE PRACTICE OF MEDICINE AND THE PUBLIC HEALTH

By James H. Beal, Urbana, Ill.

The United States Pharmacopoeia is the local standard for the purity and strength of drugs and medicines in both interstate and intrastate commerce, and as such is intimately related to the practice of medicine and the public health.

A pharmacopoeia, properly so-called, differs from other books descriptive of drugs in that it possesses an official character. Originally pharmacopoeias derived their official character from the fact that they were compiled and issued under the authority of certain colleges or universities, as the early European pharmacopoeias, or were compiled and issued under the authority of some medical or pharmaco-medical society, as in the United States.

At present every important pharmacopoeia of the world is either issued directly by some government bureau or a committee, or if issued by some non-governmental body, is adopted later by the law-making authority as a legal standard for the strength and quality of drugs and medicinal preparations. The United States Pharmacopoeia belongs to the latter class, being revised and issued under the authority of the United States Pharmacopoeial Convention, and later adopted as a legal standard for drugs and medicines by the federal and state legislative bodies.

The first United States Pharmacopoeia was prepared and issued under the authority of a convention of American physicians held in 1820.

The early editions were comparatively simple books and were usually ready for distribution within a year or so after the meeting of the convention. With the increasing size and elaboration of the volume the length of time necessary for revision has constantly increased, and the present, or ninth revision, now in press, has been in process of preparation since 1910.

The United States Pharmacopoeial Convention is incorporated under the laws of the District of Columbia. It assembles at Washington, D. C., every ten years, in the year of the decennium ending in zero, and is made up of delegates representing national and state medical societies, national and state pharmaceutical societies, recognized colleges of pharmacy and medicine, the medical departments of the U. S. Army and Navy, the U. S. Bureau of Chemistry, U. S. Public Health Service, American Chemical Society and various other scientific and professional organizations of a similar nature.

An inspection of the makeup of the convention will show that it provides for the representation of a wider range of medical, pharmaceutical and general scientific interests than could possibly be the case if the work were to be revised and issued under the auspices of any governmental department or bureau.

In the case of most foreign pharmacopoeias, the pharmacopoeia becomes part of the law of the land by virtue of its having been prepared and promulgated by some governmental agency. The United States Pharmacopoeia becomes part of the law of the land only by virtue of its adoption as such by the bodies constitutionally entrusted with the duty of law-making.

As to the relative merits of the foreign and United States pharmacopoeias, a critical inspection will usually award the palm of superior excellence to the latter. Although more democratic in its origin than the European volumes, one competent European critic has declared ours to be the "aristocrat among pharmacopoeias."

Scope and Contents of the Pharmacopoeia.—One of the surprising things to the layman is the relatively small size of the Pharmacopoeia when compared to such works on materia medica as he may have seen in libraries and elsewhere. Our present Pharmacopoeia does not run quite to 700 pages, and enumerates less than one thousand—958—drugs and medicinal preparations, while the larger volumes known as dispensatories, commonly seen in the drug stores, may aggregate as many as 2,000 pages and describe several times as many thousand drugs and preparations.

The reasons for this limitation in size of the United States Pharmacopoeia are several:

One reason is that, being the legal standard for the enforcement of the food and drug laws, the Pharmacopoeia must confine itself to such matters as are susceptible of legal proof, namely, to such matters as chemical composition, chemical and physical properties, etc. Since the therapeutic or curative properties of drugs are, and probably always will continue to be, more or less matters of opinion not susceptible of exact proof, the Pharmacopoeia can not properly deal with them, and consequently one may search that volume in vain for an expression of therapeutic opinion or for evidence as to what a drug or medicine is to be used for, except in the case of a few antidotes where some indication of the use of the substance is imperative.

A second reason for the limited size of our official drug book is that, being a legal standard, it must be a conservative volume, and admit only such drugs as have stood the test of long experience. Of the hosts of new drugs and medicinal preparations introduced each year, probably not one in a hundred stands the test of experience and remains a permanent part of the materia medica. Until a drug has successfully withstood this test, it is not fit for pharmacopoeial recognition.

A third and potent reason for the limited scope of the Pharmacopoeia is found in the fact that no article of proprietary origin, that is, no article of secret composition, or one the manufacture of which is controlled by virtue of a patent or trademark, is given recognition. That is to say, no article can be admitted into the Pharmacopoeia unless the right to manufacture it is open to all, and this regardless of its remedial value. If an infallible remedy for tuberculosis were to be discovered tomorrow it could not be admitted to the official list as long as its composition were kept secret, or as long as free competition in its manufacture was prevented by virtue of a patent or by other means.

LACK OF CONFORMITY OF MEDICAL PRACTICE TO THE U. S. P.

At the time of the publication of the first United States Pharmacopoeia, in 1820, that volume probably contained the titles of a majority of the substances then used by the medical profession. The revision in force today probably does not recognize more than 10 per cent of the substances in common medical use. Thus we have the strange situation that the volume popularly supposed to be the standard of medical practice is, as a matter of fact, practically unrecognized by the medical profession. A majority of physicians in practice today probably do not own a copy of the Pharmacopoeia, and probably never saw one.

Much of the responsibility for the failure of the medical profession to recognize and use the pharmacopoeial preparations rests upon the manufacturers of patented or otherwise protected proprietary remedies. Hosts of these proprietaries have been introduced, and as their popularity has increased with physicians, the popularity of U. S. P. remedies has declined.

The extent to which proprietary and semi-proprietary medicines are used by the medical profession cannot, of course, be determined with any degree of exactness, but it is certain that the quantity is very much greater than of the remedies recognized by the Pharmacopoeia and National Formulary. It is perhaps not strange that this should be so.

Physicians are like other people in that they are most likely to concern themselves with the things most frequently brought to their attention. No one is interested in the exploitation of non-proprietary drugs, or those which can be freely manufactured and sold by every one, and such drugs must derive their reputation for therapeutic value from the formal description of them in text books on materia medica and from the experience of those who have used them.

Proprietary remedies, on the other hand, are liberally exploited by advertising in the medical journals, by samples sent to physicians, by exhibits made at medical conventions, and by other adroit commercial methods. The physician is bombarded with literature describing the preparations and the classes of affections in which they have been found helpful, and these descriptions are not in the formal and unemotional phraseology of the text books, but in the enthusiastic language of a partisan. The physician is persuaded to try, finds a preparation effectual, and continues to use it thereafter, although it may be no better than some corresponding official preparation, or it may even be an official preparation differing only in some immaterial particular, such as color or flavor.

Owing to this extensive use of patented and other proprietary preparations by the medical profession the Pharmacopoeia might almost be said to be merely a theoretical standard for the physician, since the majority of drugs he makes use of are not found in it, and his information as to the composition and value of those he does use is derived mainly from the literature supplied by the manufacturers of such preparations. Sometimes a manufacturer gives one formula on the label, and at the same time uses a different formula—as proved by the fact that an exact following of the published formula will not reproduce the preparation—so that the composition is in fact secret, though pretending to be non-secret.

As might be expected, this large use of proprietary preparations in preference to official medicines has been productive of much controversy in medical and pharmaceutical circles. Those who support the use of U. S. P. preparations justly say, "What is the use of having an official list of medicines, if it is not observed in prescribing?" To this the physician who uses proprietaries replies, "What difference does it make to me or to my patient whether remedies I use are official or proprietary, if they produce the desired results? Proprietary remedies are put up in attractive form, are usually of pleasant flavor, and, being always made by the same firm, are uniform in strength and appearance. The manufacturer's name on the label is a guaranty of genuineness and uniformity; when I write a prescription for a proprietary I know exactly what will be dispensed. Prescriptions compounded from U. S. P. drugs by different pharmacists frequently vary in color, flavor and strength; when I order a mixture of U. S. P. drugs I do not know how the mixture will look and taste when finished."

THE READJUSTMENT OF THE U. S. P. TO MEDICAL PRACTICE

The question then is, shall we drive physicians back to the limits set by the Pharmacopoeia, or shall we extend the limits of the latter so as to suit the prevailing practice among physicians?

The readjustment of conditions so as to bring the contents of the Pharmacopoeia and the practice of medicine into something like substantial agreement is a complex and delicate problem. To arbitrarily command the physician to restrict his prescriptions to a particular list of drugs would be of itself a kind of medical sectarianism, and of a peculiarly offensive kind, since it would have to be a sectarianism supported by legal penalties.

To attempt to limit medical practice in this manner would unduly infringe upon the right of the physician to select such medicinal agents as he thought most useful, and would tend to prevent progress in the discovery and application of new medicinal agents.

We would not undertake to compel artisans to use the same kind of tools for the purpose of doing the same kind of work, but would leave it to each workman to select the tools he preferred; why, therefore, should the physician be prevented from using the tools with which he is best acquainted and with which he gets the best results?

On the other hand, it would manifestly be impossible to extend the U. S. P. so as to include the thousands of proprietary and semi-proprietary articles in common use.

Probably a compromise between these two extremes would be the better course, viz., a continuous propaganda to induce physicians to limit the range of medicaments employed by them, and also a liberalizing of the pharmacopoeial list so as to include a wider range of remedial preparations. The Pharmacopoeia already contains a list of formulas which are confessedly imitations of, or substitutes for, certain proprietary compositions of established reputation, and there is no reason why the list of official formulas should not be extended to cover all of the usual daily wants of the physician.

The drainage engineer who should undertake to regulate water-flow without regard to the natural drainage channels established by topography would certainly meet with disaster. Those who would regulate the flow of social and professional affairs must likewise take into account known tendencies and dispositions.

If proprietary remedies did not present certain advantages for the use of physicians the latter would not use them. If the official list of remedies does not afford the physician a sufficiently wide range of choice, or if they are lacking in elegance or uniformity as commonly dispensed, we cannot blame him for resorting to proprietary preparations which are especially devised with a view of meeting his desires and satisfying his convenience.

THE COMPOSITION AND ORIGIN OF MONK'S MOUND

A. R. Crook, State Museum, Springfield

Six miles east of St. Louis, in the rich bottom lands of the Mississippi Valley, are a series of about seventy mounds called the Cahokia Mounds. They vary in height from a few feet to ninety feet and in horizontal dimensions from fifteen to one thousand feet. They are scattered for more than one mile in an east to west direction. The largest of them, known as Monk's Mound, is ninety feet in height, seven hundred feet in breadth and one thousand feet in length.

For over one hundred years these mounds have been visited, studied and described by various writers, who have called them artificial mounds, built by the so-called "mound builders," or by the Indians.

The men who first expressed this idea were not physiographers or geologists. Their followers for the most part have been archaeologists rather than students of soils, of strata, of topographic forms or of fossils. Almost no opportunity has been afforded them to investigate the subject. These conditions added to the very human habit of choosing the unusual or mysterious in preference to every day matters of fact have, in my opinion, contributed to the persistence of a false conclusion.

In August, 1914, the writer was courteously permitted by the Ramey heirs to bore twenty-five holes in the north and

One of the earliest writers on the subject, Brackenridge, in a letter to Thomas Jefferson, calls Monk's Mound "the most stupendous monument of antiquity."

1813, H. M. Brackenridge, Trans. American Phil. Soc. Vol. 1, New Series 1818, Antiquities of the Mississippi Valley," page 151; 1814, H. M. Brackenridge "Views of Louisiana," Pittsburg, 1814, page 181; Baltimore, 1817, page 72. Latrobe, Vol. 2, page 250. Featherstonhaugh's "Travels in North America," page 66.

Squier called it an "Ancient monument to human labor and skill," and says "it is of course much rounded and its regularity to a great degree destroyed by the storms and changes of centuries; its original plan is however so represented as to be still sufficiently obvious."

"Smithsonian Contribution to Knowledge," 1848, Squier, Vol. 1, Preface, page XXXL; also page 174, and E. G. Squier, "Aboriginal Monuments of the Mississippi Valley." Bartlett and Welford, 1847, page 30.

"The most magnificent of all the mound builder's art."

1880, J. T. Short, "North Americans of Antiquity." Harper Bros. 1880, page 41.

"Cahokia Mound is the largest of the artificial mounds."

1885, J. S. Kingsley, "Standard Natural History," Cassinolo, 1885, Vol. 6, page 210.

"Giant structure known as Monk's Mound."

1890, 12th Annual Report of the American Bureau of Ethnology, J. W. Powell, 1890-91, Thomas, page 131-134 and 595.

"Cahokia Mound is itself a truncated pyramid, the type of a series of mounds constructed in the rich soil of the Mississippi valley."

Harlan I. Smith, "The Great American Pyramid," Harper's Magazine, Vol. 104, 1901, page 198.

"The most imposing prehistoric monument in North America."

1903, J. P. MacLean, "Mound Builders," Robert Clark Co., page 42, and H. M. Baum, "Records of the Past," Vol. 2, page 215.

"The largest artificial work in the United States."

D. I. Bushnell. "Scientific American, March 19, 1904, page 236, also "Science," November 27, 1914, page 782.

"The builders of Cahokia are gone."

1907, Clark McAdams, "Achaeology of Illinois," page 39, Trans. of the Ill. State Hist. Soc., 1907.

"We now know that these works were constructed by the immediate ancestors of the American Indian."

1908, N. S. Shaler, "Nature and Man in America," Scribner, 1908, page 182.

"At present it is positively known that the mounds are genuine antiquities made long ago. * * * by American Indians."

1909, Dr. John F. Snyder, Journal Illinois Historical Society, Vol. 2, page 88, also Vol. 5.

"The largest mass of earth artificially heaped up in the world."

1910, Warren K. Morehead, Trans. Ill. State Historical Soc., page 184.

"The largest prehistoric work in America."

Encyclopedia Britannica, Vol. 4, page 947 d. See also Lucien Carr, Memoirs Geological Survey of Kansas, P. R. Ray, Trans. Wisconsin Academy Science, Vol. 6, p. 81; Science; American Anthropologist; American Antiquarian.

most abrupt face of Monk's Mound and from them to take samples of the earth of which it is constituted. The bluffs of the river, two miles away, and the surrounding mounds, were similarly examined and the materials compared. The top of Monk's Mound (from the 500 to 490 foot contour) consists of earth similar to the loess on the bluffs at similar levels about two miles further east. It contains less calcareous materials than does the bluff earth, since the overlying soils on the bluffs, rich in lime, are wanting, and it has been thoroughly leached. Thirty feet farther down (from 460 feet to 450 feet contour) the earth is richer in sand and at one place a stratified bed of sand is in evidence. Twenty feet below this (from 430 feet to 420 feet contour) the material is a tough blue clay. The soil composing the floor of the "American Bottoms" is a loam containing sand, lime and clay.

The fact that the constituent materials are different at different levels in the large mound; that they are the same at the same elevation in mounds a mile apart and in the bluff two miles away; that they are stratified, and that they are in different order than they would be if heaped up by human labor, all show beyond doubt that Monk's Mound and neighboring mounds are natural remnants of waterborne glacial materials which once filled the valley

Further at an elevation of 485 feet is a bed of fossil hackberry seeds. These beds and other fossiliferous layers* show that the materials containing them were deposited by water.

Again, the location and physiography of the mounds clearly indicate their origin. They form the divide or water shed between Cahokia Creek on the north and the small streams flowing westward along the southern side. The contours of the mounds are typical of water carved land.

Finally it is to be doubted that Indians who were kept busy with the struggle for existence and who were naturally disinclined towards unnecessary work would erect a great mound in a region where nature had already produced an abundance of rounded hills and bold bluffs.

All of which shows that Monk's Mound was not built by man.

Dr. Snyder reports the finding of Physa heteorostropha, Limnea humilis, Helix concava and striatella, and Succinea obliqua.

The writer found a number of shells which were determined by Dr. Pillsbury of Philadelphia to be Pyramidula perspectiva; Succinea Grosvenori Lea; Helicina occulta Say., Physa gyrina.

Papers on Agriculture

THE FIRST GENERATION CROSS BETWEEN TWO STRAINS OF CORN BRED FOR HIGH AND LOW EARS*

A. M. Brunson, University of Illinois

The parents of the cross considered in this paper are the Illinois High Ear and the Illinois Low Ear strains of corn. These stains originated from the same field of Leaming corn in 1902 and have been grown in separate plots continuously since then by the Illinois Agricultural Experiment Station, and selected for High Ears and Low Ears respectively, with the results shown graphically in Fig. 1. It is my purpose to consider briefly some of the characteristics exhibited by a first generation cross between these two strains arising from the same original stock which, after having been bred divergently for eleven generations, were recombined.

The two parents and the F. generation were grown contiguously in 1-13th acre plots, duplicated, on the Plant Breeding Corn Hybrid Field in 1914. The cross was made the year before by planting and detasseling a few rows of Low Ear

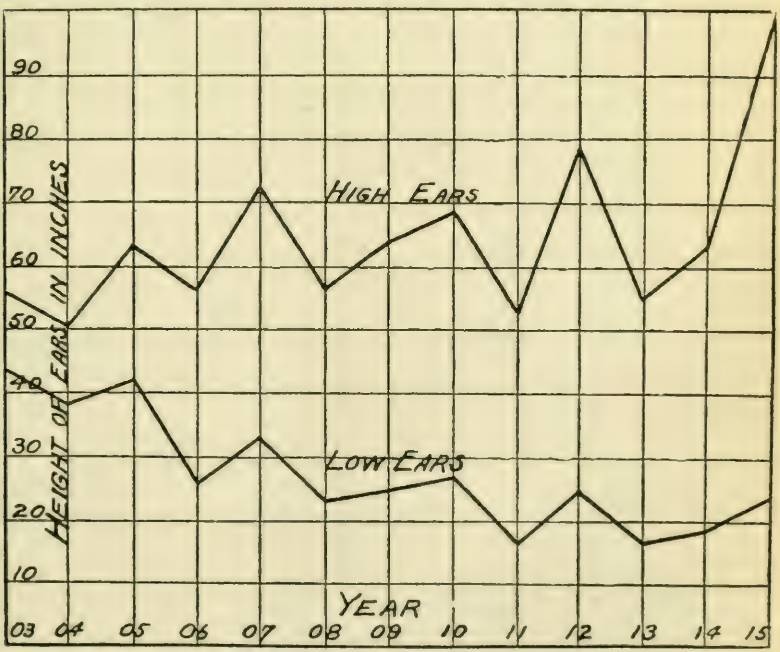


Figure 1

at one side of the High Ear plot so that the Low Ear silks were pollinated with High Ear pollen. Measurements were taken the fore part of October after all growth had ceased. By height of ear is understood to mean the length of stalk from the surface of the ground to the node from which the ear grows. In event of more than one ear the upper one is always measured as it is usually the principal ear. The number of internodes are counted from the surface of the ground to the ear-bearing node.

HEIGHT OF EAR

*Paper read before the Illinois Academy of Science, February 19, 1916.

	Low Ear	High Ear	Low Ear x High Ear
Mean	17.64±.20	68.06±.32	39.12±.25
Standard Deviation	5.34±.14	8.62±.23	6.99±.18
Coefficient of Variability ...	.303±.008	.1266±.003	.1786±.005

Probably the most obvious difference between the three strains is in the height of the ear. The mean height of the Low Ears is 17.64 inches, of the High Ears 68.06 inches, or practically four times as high; that of the cross was 39.12 inches or nearly a mean proportional between the two parents. The

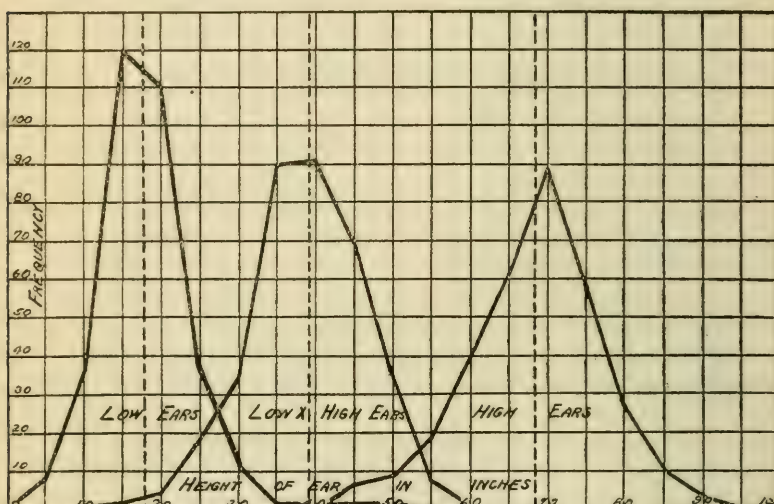


Figure 2

frequency distributions are represented graphically in Fig. 2, the height of ear in inches being plotted as abscissae and frequency as ordinates. The dotted lines represent the means. It is easily seen that the parent strains scarcely overlap at all, and that the cross is intermediate between them. The coefficient of variability in respect to height of ear of the cross is also intermediate between the coefficients of variability of the parents.

INTERNODES

	Low Ear	High Ear	Low Ear x High Ear
Average Number	4.91	10.23	7.36
Number	4.91	10.23	7.36

The number of internodes in the cross was intermediate between those of the parents, the mean number of the cross being 7.36 as compared with 4.91 in the low ears and 10.23 in the high ears. The height of ear is due not only to the number of internodes, but also to the length of internode, and in this respect the hybrid is likewise an intermediate, the average length of internodes in the hybrid being 5.32 inches, whereas in the low ears it is 3.59 inches and in the high ears 6.65 inches. Fig. 3 shows graphically the relative heights of ear in the three strains and also the average length of internode for each strain drawn to the same scale.

An interesting difference resulting from the breeding for high and low ears is in the time of maturity. Although no attention has been paid to this character in making the selections, the low ears normally mature 10 to 15 days earlier than the high ears. In 1914 the low ears required only 54 days from planting to produce tassels; the high ears required 65 days, and the cross 56 days, showing it again to be intermediate although favoring the Low Ear parent.

YIELD

	Low Ear	High Ear	Low Ear x High Ear
Bushels per acre	48.4	44.4	66.4

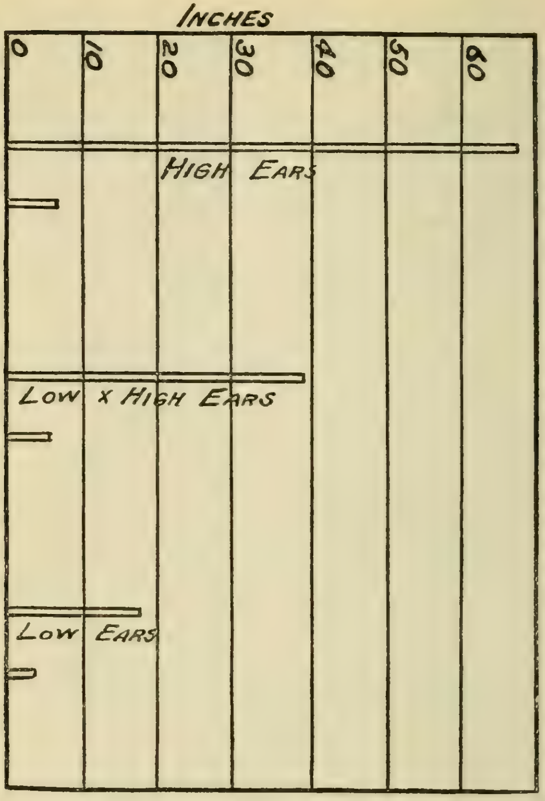


Figure 3

The parent strains have been close-bred for so long that their vigor is somewhat impaired, and the yield of grain is not as high as in the ordinary Leaming corn. In 1914 the High Ear plot yielded 44.4 bushels per acre, the Low Ear plot 48.4 bushels, and the F_1 cross 66.4 bushels per acre, or 37 per cent more than the higher yielding parent and 27 per cent more than a standard strain of Leaming growing close by. While we have not the original stock from which the parent strains sprang, with which to compare these yields, we are probably safe in assuming that the vigor of the cross is at least as great as in the original stock.

We see, then, that the first generation cross between the high and low eared strains gives a type of corn on which the height of ear is intermediate between the two parents and which, allowing for seasonal variations and fertility differences, probably approximates the height of ear of the original stock. The hybrid was reasonably uniform in respect to height of ear, its coefficient of variability being intermediate between those of the parents. In number of internodes below the ear and average length of internode, the cross was intermediate between the parents. The time required for maturity was intermediate in the cross, although favoring the Low Ear parent. In yield of grain, however, the cross gave an increase of 37 per cent over the higher yielding parent and 27 per cent over a nearby plot of Leaming, the variety from which the parents originated. It may be said then that in respect to certain physical measurements, for which the two strains have been divergently selected, the cross gives us values closely approximating the original variety, and in respect to yield the vigor lost to some extent by close breeding is fully restored.

EFFECT OF ALTITUDE UPON THE COMPOSITION OF FORAGE PLANTS

Henry G. Knight, University of Illinois

There is little question that a knowledge of the effects of altitude upon the growth and composition of plants is important not only from a scientific standpoint, but also for practical reasons. A better knowledge of these effects and the primary causes which go to produce them will undoubtedly throw some light upon our problems and help us to understand better the effects of slight changes of altitude which may be difficult to determine directly. Then, too, this subject is of special importance to those who are interested in agricultural practice at the higher altitudes.

Between the altitudes of 4,500 feet and 7,500 feet there are three Agricultural Experiment Stations in the United States —Utah Station at Logan, altitude 4,500 feet; Colorado Station at Fort Collins, altitude 5,000 feet, and Wyoming Station at Laramie, altitude 7,200 feet. The altitude of the last named station is at about the limit of successful agriculture for the latitude in which it is situated, but in the mountainous sections of the world there are considerable areas of land in the aggregate between the elevations of the Utah and the Wyoming stations, which are devoted to successful agriculture and in the three states in which these stations are located there are more than a million acres, so the subject becomes of some importance locally.

It is generally known that the environmental factors vary with change in altitude, but the extent of the change is not so well understood, empirically an increase of a thousand feet in altitude is equivalent to a shift of 300 miles from the equator, so it would be possible upon land elevated at the equator to have all the zones with corresponding flora and fauna. Actually, however, conditions are not the same as, but similar to, the zonal.

The higher altitudes are marked by the following peculiar climatic conditions, which are not necessarily peculiar to changes in latitude:

A marked daily range of temperature which increases with altitude.

Mean daily temperature decreasing with altitude.

Comparatively high solar radiation.

Prevailing high winds, increasing with altitude.

Comparative high evaporation because of the lowered air pressure.

As we pass to the higher altitudes the following changes are noted in vegetation:

The less hardy varieties and species give place to the more hardy.

The average height of the plants of any species decreases.

The proportion of plant above ground to that below decreases.

The proportion of seed to stock and leaves tends in general to increase.

The period between germination and seeding decreases.

Decreased acre yields.

A greater resistance to frosts.

All of these known changes would be expected to produce an effect upon the vegetation.

Investigations were begun at the Wyoming Experiment Station several years ago (Wyoming Forage Plants and Their Chemical Composition. Bulletins Nos. 65 (1905); 70 (1906); 76 (1908); and 87 (1911). Knight, Hepner and Nelson) which seemed to throw some light upon the change in composition of plants with change in altitude.

Samples of native forage plants were collected at various altitudes, but otherwise under as near similar conditions as possible.

Table I gives the complete approximate analyses of some of these native plants.

TABLE I.

Mountain Timothy

Year	Altitude	Ash	Ether Ext.	Crude Fiber	Nitrogen X6.25	N. Free Ext.	No. Samples
1905	7500	3.82	1.78	39.74	5.00	46.99	1
1909	9500	5.15	1.69	38.54	9.59	45.03	1
1908	10000	4.47	2.35	30.69	11.46	51.03	1
1909	10000	4.31	1.66	35.66	9.43	48.94	1
1907	10500	4.54	2.55	31.84	12.04	49.03	1
			Bearded Wheat Grass				
1905	7000	8.31	1.95	36.64	7.85	45.25	1
1905	7500	6.02	1.96	37.09	8.28	46.65	1
1909	9500	4.73	2.00	36.15	8.56	48.56	1
1909	10000	4.98	1.49	36.97	14.05	42.51	1
			Western Wheat Grass				
1908	4300	8.63	2.68	37.31	8.70	42.67	2
1908	7200	8.93	2.11	34.18	10.92	43.68	1
1905	7200	8.31	2.24	33.94	10.19	45.32	4

It will be noted that the nitrogen content increases with the altitude, while there are no regular changes to be noted in the other plant constituents. As further evidence of the change in nitrogen content with changes in altitude Table II is given.

TABLE II.

Name of Plant	Altitude	Year	N. X. 6.25	No. of Samples
Tufted Hair Grass	10800	1907	10.95	1
Tufted Hair Grass	11000	1907	17.93	1
Tufted Hair Grass	7200	1908	6.07	1
Tufted Hair Grass	10500	1908	12.98	1
Mountain Blue Grass	10000	1908	9.36	1
Mountain Blue Grass	10500	1908	11.87	2
Mountain Spear Grass	8000	1909	7.78	1
Mountain Spear Grass	10000	1909	8.18	1
Fine Topped Salt Grass	4300	1908	7.79	2
Fine Topped Salt Grass	7100	1908	12.82	1
Canadian Needle Grass	9500	1909	7.79	2
Canadian Needle Grass	10000	1909	11.21	1

Downy Oat Grass	10000	1907	9.69	1
Downy Oat Grass	11000	1907	12.20	1
Giant Sedge	9500	1908	10.00	1
Giant Sedge	10000	1908	11.76	1
Mountain Sedge	9500	1908	13.26	1
Mountain Sedge	10500	1908	15.76	1
Mountain Sedge	8000	1909	7.12	1
Mountain Sedge	10000	1909	12.37	1
Parry's Rush	9500	1909	11.96	1
Parry's Rush	10500	1909	16.75	1
Western Wheat Grass	4300	1908	8.71	2
Western Wheat Grass	7200	1908	10.92	1
Rough Hair Grass	8000	1909	7.47	1
Rough Hair Grass	10000	1909	9.87	1
Slough Grass	8000	1905	6.33	1
Slough Grass	8500	1905	7.54	1

As a summary of forage during the years 1908, 1909 the following table is given:

TABLE III.

No. of Samples	Altitude	N. X. 6.25 1908	1909
39	4100 to 4500	8.29	
1	4700	12.59	
1	5700	9.09	
6	7200	9.63	
4	8000		8.55
1	8500	7.08	
3-9	9500	8.56	8.97
5-14	10000	10.85	10.40
9	10500	12.32	
1	11000	12.30	
	Sedges		
3	4200 to 4500	9.53	
1	7100	8.09	
1	8000		7.99
4-4	9500	12.76	13.46
6-7	10000	13.56	12.11
3	10500	14.16	
1	11000	18.77	

The nitrogen content of the forage plants increases with altitude. It was believed that this might be explained by differences in soils, but investigations with this in view have not thus far supported this theory. The other accepted factors such as light, heat, air and moisture have been given consideration, but no one of them seems to afford an adequate explanation, but the changes in the first four together are the probable cause of the difference noted. Under the more adverse conditions of the higher altitudes plants must in a shorter time come to the fruiting period if the species are to survive. Since seed require larger proportions of nitrogen than the foliage, we would, since the weight of foliage becomes less, expect that a higher nitrogen content would be found in the foliage of the plants at higher altitudes in preparation for the fruiting period.

CONCLUSIONS

The nitrogen content of forage plants increases with altitude.

No regular changes were noted in the other plant constiuents as represented by the approximate analysis.

The probable cause is the change in habitat of the plants due to change in general climatic conditions.

THE ARTIFICIAL GERMINATION OF MAIZE POLLEN

By L. H. Smith and D. I. Adronescu,* University of Illinois

While the pollen of many kinds of plants germinate very well in water or even in moist air, others require the presence of certain substances in solution. A sugar solution offers such a medium in quite a number of species while in other cases this must be either replaced or else combined with some other substance, sometimes organic, sometimes inorganic, in nature. In some instances a decoction of the stigmatic parts has been found to be essential in inducing germination of the pollen.

Although certain authors have claimed to have successfully germinated maize pollen, attempts to repeat their work have resulted only in failure for us, altho we have tried repeatedly with a considerable number of different substances used as substrata.

Immersed in water, the pollen grains rapidly absorb moisture until they suddenly burst. The same is true in the case of many solutions, although this action is more or less retarded. With other solutions, instead of this sudden rupture, the pollen cells were seen in the course of a few minutes to eject long streams or sprouts of protoplasm, often curling and twisting in all directions, and with such force as to throw the pollen grain backward in recoil. These filamentous ap-

*The data for this report were collected by the junior author in connection with a thesis entitled "The Physiology of the Pollen of Zea Mays with Special Regard to Vitality."

TABLE I.

Germination Experiments in Single Solutions

Solution	Concentration 5%	10%	15%	20%	25%	30%
Sucrose	Burst	Burst 20%	Burst 10%	Burst 10%	Burst 4%	Turgid
Lactose	Burst	Burst 60%	Burst 60%	Burst 60%	Burst 50%	Burst 20%
Maltose	Burst	Burst 60%	Burst 60%	Burst 60%	Burst 60%	Burst 20%
Dextrose	Burst	Burst 80%	Burst 80%	Burst 60%	Burst 60%	Burst 20%
Levulose	Burst	Burst	Burst 80%	Burst 80%	Burst 70%	Burst 60%
Arabinose	Burst	Burst 90%	Burst 90%	Burst 80%	Burst 60%	Burst 40%
Glycerine	Burst 20%	Burst 20%	Burst	Burst	Burst	Burst
			Turgid	Turgid	Turgid	Turgid
Gelatin	Burst	Pseudo-germi'tion	Pseudo-germi'tion	Pseudo-germi'tion	Pseudo-germi'tion	Pseudo-germi'tion
Gum Arabic	Burst 40%	Pseudo-germi'tion	Pseudo-germi'tion	Pseudo-germi'tion	Pseudo-germi'tion	Pseudo-germi'tion

pendages varied in length, being sometimes from 25 to 30 times as long as the diameter of the pollen grain itself. Some were very slender and threadlike, others were proportionately thicker. To this phenomenon we have applied the name "pseudo-germination" Altho at first sight this protoplasm expansion might be mistaken for germination tubes, closer examination easily reveals the distinction, for they lack most of the essential characteristics. In the first place the expansion is far too rapid to represent actual growth. Then there is no enveloping membrane surrounding the protoplasmic substance as in the true germination tube. The resemblance is close enough, however, to suggest the possibility of this phenomenon having been mistaken for real germination in some of the previously reported work referred to above.

It is interesting to note that only fresh pollen is able to send out these protoplasmic sprouts, old pollen remaining turgid and inactive.

METHODS

For this investigation fresh pollen was used, the tassels being collected and brought into the laboratory early in the day of the experiments. The observations were made by means of the hanging drop cultures. The special precaution against the use of impure water in making up the solutions was taken by redistilling the water from glass vessels.

RESULTS

We first tried a series of simple solutions taken in varying strength from 5 to 30 per cent, and table I gives the results.

TABLE II.

Germination Experiments in Mixed Solutions

Solution	Concentration	Behavior
Sucrose Lactose	10% 10%	In 20 minutes 50 % burst
Sucrose Lactose	15% 15%	In 20 minutes 20% burst
Sucrose Dextrose	10% 10%	In 20 minutes 20% burst
Sucrose Dextrose	15% 15%	In 20 minutes 20% bust
Sucrose Lactose Maltose Dextrose	5% 5% 5% 5%	In 20 minutes 50% burst
Sucrose Malic Acid	20% 0.01%	Bursting 4%; 44% pseudo-germination, protoplasmic expansion 20 times diameter of pollen.
Sucrose Malic Acid	5% 0.01%	Burst
Sucrose Malic Acid	20% 0.05%	Turgid
Sucrose Citric Acid	5% 0.02%	Burst 50%. Some pseudo-germination.
Sucrose Citric Acid	10% 0.02%	Burst 10%. Pseudo-germination, 20%.
Sucrose Citric Acid	20% 0.05%	Turgid.

Solution	Concentration	Behavior
Sucrose Asparagin	15% 0.1%	In 10 minutes 85% burst
Sucrose Asparagin	15% 0.5%	In 10 minutes 60% burst
Sucrose Lipase	15% 5%	Some bursting, some pseudo-germination
Sucrose Lecithin	15% 5%	Some bursting, some pseudo-germination.
Sucrose Saltpeter	20% 0.5%	Turgid
Sucrose Gum arabic	5% 5%	In 5 minutes 90% burst
Sucrose Gum arabic	2.5% 7.5%	In 5 minutes many bursting, some pseudo germination
Sucrose Gum arabic	1% 9%	Burst 30%; many pseudo-germinations
Sucrose Gum arabic	7.5% 2.5%	In 10 minutes 50% burst; some pseudo germination.
Sucrose Gum arabic	9% 1%	Bursting
Sucrose Gum arabic	15% 15%	In 10 minutes 80% burst
Sucrose Gelatin	5% 5%	Burst 30%
Sucrose Gelatin	2.5% 7.5%	Burst 20%; pseudo-germination 10%
Sucrose Gelatin	1% 9%	Burst 20%; some pseudo-germination
Sucrose Gelatin	7.5% 2.5%	Burst
Sucrose Gelatin	9% 1%	Burst
Sucrose Gelatin	15% 15%	Pseudo-germination with very thin and long protoplasmic extension Burst 2%
Lactose Gelatin	15% 15%	In 10 minutes 60% pseudo-germination
Dextrose Gelatin	15% 15%	In 10 minutes 40% pseudo-germination
Sucrose Dextrose Lactose Maltose Gelatin	5% 5% 5% 5% 25%	Pseudo-germination 80%, with thin and long protoplasm extension
Gelatin Malic acid	5% .01%	Some pseudo-germination; Burst 30%
Gelatin Citric acid	5% .01%	Pseudo-germination 50%; burst 30%
Gelatin Sucrose Citric acid	5% 4% 0.01%	In 30 minutes pseudo-germination 94%
Gelatin Citric acid	5% 0.5%	Burst 6%. Turgid
Gelatin Lipase	10% 1%	Burst 80%; very few pseudo-germinations.
Gelatin Saltpeter	10% 0.05%	Turgid

Solution	Concentration	Behavior
Gelatin Sucrose Saltpeter	10% 5% 0.05%	Turgid
Gelatine Asparagin	19% 0.1%	Pseudo-germination 90%
Gelatin Arabinose	10% 2%	Pseudo-germination 70%
Gelatin Lecithin	10% 2%	Pseudo-germination 60%, with heavy protoplasm extension
Gum arabic Glycerine	20% 50%	Pseudo-germination 95%, very thin and long protoplasm extension
Gum arabic Sucrose Citric acid	10% 5% 0.02%	Turgid
Gum arabic Arabinose	10% 2%	Pseudo-germination 90%
Gum arabic Arabinose Citric acid	10% 2% 0.01%	Pseudo-germination 40%
Levulose Lecithin	15% 1%	Bursting; very few pseudo-germinations
Gum arabic Asparagin	10% 0.1%	Pseudo-germination 40%
Arabinose Lecithin	10% 1%	Burst 80%; very few pseudo-germination
Arabinose Malic acid	15% 0.01%	Turgid
Arabinose Citric acid	15% 0.01%	Turgid

In no case does germination appear. In general we see that the sudden bursting becomes less prevalent as the concentration increases.

For example, in cane sugar, in the weak solution all the pollen grains burst, but as the concentration increases, fewer and fewer rupture until at 30 per cent this is entirely prevented. The other sugars behave in the same general manner as sucrose, but with less efficiency in preventing rupture. With gelatin and gum arabic this sudden bursting ceases with concentrations at 10 per cent and above, and then pseudo-germination appears.

The next trials were made with a series of combinations or mixed solutions and the results of these tests are set forth in table II.

TABLE III.

Germination Experiments in Solutions of Sucrose and Agar

Solution	Concentration	Germination
Sucrose Agar	5% 0.15%	Burst 10%; Turgid
Sucrose Agar	10% 0.15%	Turgid; Burst 6%; Germination 5%
Sucrose Agar	15% 0.15%	Burst 5%; Germination 5%; Turgid
Sucrose Agar	20% 0.15%	Burst 2%; Germination 10%; Turgid
Sucrose Agar	25% 0.15%	Germination 10%; Turgid
Sucrose Agar	30% 0.15%	Burst 2%; Germination 16%; Turgid
Sucrose Agar	15% 0.02%	Burst 90%; no germination.
Sucrose Agar	15% 0.03%	Burst 40%; Germination 6%; Turgid
Sucrose Agar	15% 0.04%	Burst 40%; Germination 6%; Turgid
Sucrose Agar	15% 0.05%	Burst 12%; Germination 18%; Turgid
Sucrose Agar	15% 0.06%	Burst 6%; Germination 25%; Turgid
Sucrose Agar	15% 0.08%	Burst 2%; Germination 15%; Turgid
Sucrose Agar	15% 0.10%	Burst 2%; Germination 16%; Turgid
Sucrose Agar	5% 0.70%	In 10 minutes germinated 4%; burst 8%; after one hour germinated 70%; burst 10%
Sucrose Agar	10% 0.70%	In 10 minutes germinated 4%; after one hour, 75%; tube long 3-5 times diameter of pollen.
Sucrose Agar	15% 0.70%	Burst 20%; Germination 20%; Turgid
Sucrose Agar	20% 0.70%	No germination; Turgid
Sucrose Agar	25% 0.70%	Turgid

In none of the fifty combinations tried were we able to observe any sign of real germination. It was not until a combination of sucrose and agar was used that germination took place.

Table III shows the series of varying concentrations and proportions of the sucrose-agar mixture tried and it is interesting as bringing out the fact that it is necessary to have not only the proper substances in order to induce germination, but they must be present in the proper proportion and concentrations.

While more or less germination takes place in most of the various concentrations tried, it appears that after a certain concentration of sucrose with agar is reached, (20 per cent), germination ceases altogether. The optimum conditions for germination were furnished by a solution of 10 per cent sucrose with 0.7 per cent agar.

INCOMES OF DAIRY FARMS

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Farmers are a conservative class of people and are engaged in a conservative business. The average operator's labor income secured from 765 farms in 1912, was $636, or about $2 per day. The incomes varied from $1,797 to $5,602. These extremes although quite divergent are relatively trivial when compared with the immense fortunes and great financial failures in our industrial centers. Agriculture is characterized by individualism, and has not shown any great inclination toward concentration of production. In this respect it differs from many urban industries. The fact that agriculture is a highly decentralized and individualistic industry, forces it to be a conservative business and as such it affords no chance for accumulation of great fortunes or suffering from great losses.

As previously stated, agriculture pays to the operator in this region an average labor income of $636. This income, altho not large, is considerably above the average wage paid to farm labor, and is a stimulus to keep good men in agriculture. These incomes, however, are not large enough to attract to the farms any considerable part of our urban population nor any great amount of the capital concentrated in our large cities.

The discussion must not be misconstrued to mean that agriculture has paid in the past or will in the future pay as good returns as it does today. Agriculture has had its "good times" and its "hard times," which may or may not coincide with the same periods in the industrial world. There is a continual race between agricultural production and demand for agricultural produce. It is only natural that each should alternately lead. In the '80s and '90s production led demand, prices were low, and consequently the profits of agriculture were small. Prices were high because demand led supply and there was a prosperous era for the farm operator.

OPERATORS LIVING ON INTEREST, UNPAID LABOR, OR OUT OF CAPITAL.

From the data secured from 765 farms it was found that 164 farms secured labor incomes of less than $1. This means that one-fifth (21.6 per cent) of all operators in this region live on interest or unpaid labor, or out of capital. It is unfortunate that so high a percentage as one in every five farmers lives not on the current surplus which he has created by productive labor, but on his family labor and interest on his capital, or by impairing his capital. An operator during his productive life is rarely justified in living on his capital unless he suffers from a destruction of capital or losses due to causes over which he has no control.

Among those living on their interest are found many of the older men who have worked hard producing commodities for society and accumulating wealth for themselves. Very few question whether these men are justified in retiring and enjoying the results of their labor. Many of these men desire, however, to remain on the farm during the rest of their natural lives instead of moving to town. In general it would probably be better if a farmer of this kind rented his farm to a younger man and lived in a house on the farm instead of continuing to run the place. The farm rented to a young man will usually be operated more efficiently than it would be by an owner who has passed the prime of life. It is hard to vindicate any group of individuals who live on the interest of their farm investments during their productive period, except during times of financial loss due to causes over which they have no control.

The fact that 2.5 per cent of the operators live on the unpaid labor of the family is evidence that these families are not so

[1]In this discussion it must be borne in mind that 5 per cent is the rate used in calculating the interest on capital. That this is a conservative rate hardly seems to need discussion; but many of the old men who have worked hard and passed the most productive part of their lives are satisfied with less than 5 per cent upon the present valuation of the land. These older men may have secured the land when it was cheap and at its cost price it may now be yielding a good return. In their opinion the land may now be over capitalized.

productive as other farm families. If these families, or some members of these families, can get better positions elsewhere it might be better for them to accept them.[2]

Some men who are making good incomes exploit family labor to acquire more wealth. Exploitation of labor from greediness and laziness must be condemned, but in other cases the defect is not so much a moral one as a lack of ability to make the most out of labor and capital.

In the struggle for existence many farmers who lack capital or business ability, or both, would be forced to the wall were it not for the labor of the various members of the family. For a family in this state of economic life it is expedient that the other members work with the operator. If all the members of the family must work, and can do no better elsewhere, it is perhaps better that they should work as a unit on their farm, rather than be scattered in the shops and factories of our large cities.

Table I.—Per cent of the total farmers living out of their capital, interest, or unpaid labor.[3] Owners, part owners, cash rent and share rent. 765 farms.

Groups	Percentage of the Total number of				
	Total	Owners	Part Owners	Cash Renters	Share Renters
Percent of farmers living on interest capital and unpaid labor	21.6	28.0	27.7	15.2	16.0
Percent of farmers living on interest	14.5	24.6	17.0	3.7	1.3
Percent of farmers living out of capital	4.6	2.8	8.5	5.3	6.0
Percent of farmers living on unpaid labor	2.5	0.6	2.2	6.2	8.7

It will be noted from Table I that one share tenant in eleven (8.7 per cent) lives on the product of the family labor. In contrast to this only 0.6 per cent of the owners live on unpaid labor. Necessity forces the share renter to utilize not only his own labor but often the labor of his family as far as possible. This causes renters more than owners to rely on unpaid labor. The owners also have a larger income of interest, which prevents most of them from falling into this class. Another rea-

[2]This discussion does not include any incomes secured by members of a family hired out to neighbors. It includes only those who work on the farm without any specific remuneration.

[3]Under unpaid labor is included all family or other labor for which no definite remuneration has been made. The term "unpaid labor" must not be construed to mean that this labor costs the farmer nothing. It merely means that no specific remuneration has been made for it. If the cost of producing and maintaining the kind of labor were considered, it is doubtful if labor secured from the boy between 10 years and 21 years, would justify the expenditure.

son why the owners are not living on unpaid labor is because they are older men than the tenants and their families are more mature and have either started farming for themselves or shifted to other occupations.

In the case of owners, one in every four (24.6 per cent) lives on his interest; while in the case of share renters, but one farmer in every 77 (1.3 per cent) lives on the product of his capital. Between these extremes we find 17 per cent of the part owners and 3.7 per cent of the cash renters living on the interest of their capital. As the capital and age of operators increase between the groups of share renters and owners there is an increasingly larger number of operators living on interest.

The largest per cent (6 per cent) of operators living on their capital is found among the share renters, and the smallest among the owners.[4]

The share renter has only a small amount of capital and therefore a small income from interest. Consequently in most cases of unforeseen losses, such as uncommon losses of stock, exceptional destruction of machinery, or false judgment in the daily routine, the share renter must fall back on his capital. The owners having large incomes from interest usually find these sufficient to tide them over periods of financial stress and therefore do not draw upon their capital.

[4]Part owners are not considered in this discussion, since the numbers are too small to assure accuracy.

THE INFLUENCE OF THE AMOUNT OF RATION AND THE ADDITION OF A NITROGENOUS CONCENTRATE UPON THE EFFICIENCY OF RATIONS FOR FATTENING PURPOSES

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INTRODUCTION

An experiment was conducted at the Illinois Agricultural Experiment Station by H. W. Mumford, H. S. Grindley, L. D. Hall and A. D. Emmett to study the effect of variations in the amount and character of the ration upon the nutrition of steers. As indicated by the title, this paper is a brief summation of the data relating (1) to the effect of the amount of the ration upon its efficiency for producing gains, and (2) to the effect of replacing a part of the corn by an equal amount of linseed meal upon the efficiency of the ration for producing gains.

The animals used were sixteen 2-year-old high-grade Hereford steers from the same herd grading as choice feeders and weighing from 750 to 1,000 pounds.

To determine the effect of variations in the amount of feed consumed upon the efficiency of the gains, the steers were divided into four lots of four animals each. One lot was given just enough feed to maintain the weights of the steers about constant, although as a matter of fact, they made considerable gain during the first and fourth periods of the experiment; another, as much as the steers would eat readily; another, an amount of feed equal to the maintenance ration plus one-third of the difference between the maintenance and the full-feed rations; and another an amount equal to the maintenance ration plus two-thirds of the difference between the maintenance and full-feed rations. In the discussion and tables of this paper the first of the above-described lots has been designated as the "maintenance" lot; the second, as the "full-feed" lot; the third, as the "one-third-feed" lot; and the fourth, as the "two-thirds-feed" lot.

The feeds used were ground corn and clover hay in different proportions and later, old process linseed meal. For the purpose of this discussion the experiment may be divided into four test periods varying in length from five to thirteen weeks.

Between the test periods were transitional periods of two or three weeks during which time gradual changes were made in the ration. Table 1 shows the test periods, the experimental weeks included in each, and the proportions of hay, corn and linseed meal in the ration of each period.

INFLUENCE OF AMOUNT OF RATION

The practical cattle feeder assumes that the larger the amount of feed fattening cattle consume the more efficient will be the gains. This assumption is based upon the fact that a certain amount of feed is required for maintenance under any condition. Consequently, the larger the amount of feed consumed, the more there is above the maintenance requirement available for production, and consequently the ration should be more efficient.

On the other hand, experiments at the Illinois, Missouri and other stations show that large rations are not as completely digested as smaller ones, especially when there is a considerable amount of crude fiber in the ration. Consequently, if one considers only the digestibility of the ration, one would expect the efficiency to be lessened as the ration is increased. Thus in studying the influence of the amount of ration upon efficiency, both of these factors, working in opposite directions, must be considered.

Table 1 shows the average amount of feed consumed per head daily by each lot during the different test periods. It will be noted from this table that the full feed consumed only a moderately heavy ration. Also it is seen that the amount of feed consumed decreased after Period 2.

The individual weights of the steers at the beginning and end of each period are given in Table 2. The average daily gains for each period and for the entire experiment are given in Table 3.

Disregarding the maintenance lot for obvious reasons, it is seen that the rate of gain decreased regularly during Periods 1, 2 and 3, even though the proportion of roughage to concentrates was considerably decreased. After the introduction of the linseed meal in Period 4 the gains were increased considerably.

Table 4 shows the amounts of feed consumed per pound of gain during each period and during the entire experiment. Table 5 shows the same results expressed in terms of total dry substance per pound of gain. Table 6 shows the individual results. (It should be noted that the values in Table 5 are not averages of the values in Table 6, but are obtained by dividing the total amount of dry substance consumed by each lot by the total gains made by the corresponding lot.) Referring to the data concerning the one-third, two-thirds and full-feed lots, it is found that in Period 1 the two-thirds-feed lot apparently was slightly more efficient than the full-feed lot. There does not seem to be much difference between the full-feed and one-third-feed lots. In Period 2 there is an indication that the one-third-feed lot was slightly more efficient than the two-thirds and full-feed lots, which seem about equal. However, the individual variations are so great that the results are not at all conclusive. In Period 3 there may be a slight indication that the efficiency of the ration varied inversely with the amount. Again the individual differences are so great that no definite conclusion is justified. In Period 4 the full-feed ration apparently was more efficient than either of the other rations, although the individual results again were rather variable. Taking the entire thirty-seven weeks of the experiment into consideration there seems to be no reason to conclude that the amount of feed consumed had any effect upon the efficiency of gains. As a matter of interest we have presented in Table 7 the coefficients of digestibility of the dry substance of the rations during the different periods.

INFLUENCE OF INTRODUCTION OF LINSEED MEAL

A comparison of Periods 3 and 4 provides data for studying the influence upon the efficiency of the ration of substituting linseed meal for an equal weight of corn in the ration. A study of Table 4 shows that in case of the one-third-feed lot, about 15 per cent more feed was required to produce a pound of gain, when no nitrogenous concentrate was fed than when linseed meal was substituted for an equal amount of corn. In the two-thirds-feed lot 23 per cent more feed was required to produce a pound of gain in the corn period than in the corn and linseed meal period. In the full-feed lot 54 per cent more feed was required to produce a pound of gain when corn was the sole concentrate than when linseed meal was also used. In this connection one should remember that if the same ration had been fed in Periods 3 and 4 we would have expected that more feed would be required in Period 4, as the steers were more nearly finished in this period. However, before drawing any definite conclusions from these data one should refer to the data of the individual animals, owing to the small number in each lot. It will simplify the study if one speaks in terms of dry substance per pound of gain rather than in terms of corn, hay and linseed meal per pound of gain.

Referring again to Table 5 the same relative differences between lots are shown as in Table 4.

Table 6 shows the individual data pertaining to the amount of dry substance per pound of gain.

Concerning the individual steers of the one-third feed lot it is found that the ration of Steer 666 was much more efficient after the addition of the linseed meal. On the other hand, the ration of Steer 662 was considerably less efficient after the linseed meal was introduced into the ration. In case of the two steers of this lot the rations were slightly less efficient after the change was made. Consequently, in view of the wide variation in individual results, it does not seem safe to conclude that the introduction of oil meal had any effect upon the efficiency of the rations of the steers of the one-third-feed lot.

Referring to the data concerning the steers of the two-thirds-feed lot it is seen that the rations of Steers 668 and 665 were considerably more efficient after the introduction of linseed meal. Steer 652 also shows a slight difference in favor of the linseed meal. Steer 657 shows little influence of the linseed meal. This may be accounted for, in part at least, as this steer was off feed and scoured some for several days in Period 4. Taking this into consideration, it seems safe to conclude that the introduction of linseed meal into the ration of the two-thirds-feed lot materially increased the efficiency of the ration.

Considering the steers of the full-feed lot, it is seen that the introduction of the linseed meal increased the efficiency of the ration to a marked degree in some cases of Steers 659, 661 and 664. Steer 663 made less efficient gains after the introduction of the linseed meal. This was doubtless due to the fact that this steer went off feed and scoured badly during the twenty-eighth, twenty-ninth and thirtieth weeks of the experiment. In fact he was so bad that he was removed from the experiment at the end of the thirtieth week and placed upon another ration. Taking this into consideration, it seems safe to conclude that the introduction of linseed meal into the ration of the full-feed lot caused a marked increase in the efficiency of the ration.

These results indicate at least that the introduction of linseed meal into the ration had a more beneficial effect in case of the full-feed lot than in case of the two-thirds-feed lot, and that it had a more beneficial effect in case of the two-thirds-feed lot than in case of the one-third-feed lot. As a matter of interest, we have presented in Table 8 the co-efficients of digestibility of the dry substance of the digestion steers in Periods 3 and 4.

CONCLUSIONS

1. In Period 1 when the ration consisted of clover hay one part and ground corn one part, the two-thirds-feed lot was slightly more efficient than the full-feed lot. There was no difference between the one-third and full-feed lots.

2. In Period 2 when the ration consisted of clover hay one part and ground corn three parts, there is an indication that the one-third-feed lot was slightly more efficient than the two-thirds or full-feed lots, which were about equal in efficiency.

3. In Period 3 when the ration consisted of clover hay one part and ground corn five parts there is a slight indication that the efficiency of the rations varied with the amounts fed.

4. In Period 4 when the ration consisted of clover hay one part, ground corn four parts and linseed meal one part, the full-feed lot apparently made more efficient gains than the other two lots.

5. Taking into consideration the entire feeding period, the amount of the ration had no effect upon the efficiency.

6. The introduction of linseed meal into the ration of the one-third-feed lot apparently had little or no effect upon the efficiency of gains.

7. The introduction of linseed meal into the ration of the two-thirds-feed lot caused a considerable increase in the efficiency of the ration.

8. The introduction of linseed meal into the ration of the full-feed lot caused a marked increase in the efficiency of the ration.

9. The introduction of linseed meal into the ration caused a greater increase in the efficiency of the full-feed lot than in the efficiency of the two-thirds-feed lot.

TABLE 1.—AVERAGE FEED CONSUMED DAILY PER LOT
(Results expressed in pounds)

Period	No. of weeks	Ratio of hay to corn to oil meal	—Maintenance Lot—			-One-third Feed Lot-			-Two-thirds Feed Lot-			Full Feed Lot		
			Clover hay	Ground corn	Oil meal	Clover hay	Ground corn	Oil meal	Clover hay	Ground corn	Oil meal	Clover hay	Ground corn	Oil meal
1	1- 5	1:1:0	5.48	5.48	....	7.88	7.88	....	10.29	10.29	....	12.13	12.13	....
2	8-13	1:3:0	2.22	6.65	....	3.74	11.22	....	5.26	15.79	....	6.45	19.36	....
3	17-22	1:5:0	1.36	6.78	....	2.23	11.12	....	3.11	15.54	....	3.53	17.62	....
4	25-37	1:4:1	1.62	6.47	1.62	2.33	9.31	2.33	2.97	11.87	2.97	3.52	14.09	3.52

TABLE 2—WEIGHTS OF STEERS AT BEGINNING AND END OF EACH PERIOD

(Results expressed in pounds)

Period	No. of weeks	Ratio of hay to corn to oil meal	Maintenance Lot Animal 653	Animal 650	Animal 656	Animal 658	Average	One-third Feed Lot Animal 667	Animal 666	Animal 669	Animal 662	Average
1	1	1:1:0	762	814	809	870	814	832	849	901	910	817
1	5	1:1:0	802	852	834	874	840	852	886	920	938	899
2	8	1:3:0	852	864	869	892	869	871	932	978	987	942
2	13	1:3:0	841	865	869	893	867	892	951	988	1017	962
3	17	1:5:0	859	879	882	904	881	1007	1000	1053	1100	1040
3	22	1:5:0	862	870	869	920	880	1045	1002	1070	1139	1064
4	25	1:4:1	834	895	891	913	883	1048	1027	1115	1173	1001
4	37	1:4:1	991	1087	934	965	994	1191	1197	1220	1247	1214
			Two-thirds Feed Lot Animal 668	**Animal 652[1]**	**Animal 665**	**Animal 657**	**Average**	**Full Feed Lot Animal 659[2]**	**Animal 663[3]**	**Animal 661**	**Animal 664**	**Average**
1	1	1:1:0	824	869	886	1010	897	894	873	1004	932	926
1	5	1:1:0	864	913	940	1043	940	948	948	1047	983	981
2	8	1:3:0	907	977	1018	1127	1007	1016	1019	1109	1028	1043
2	13	1:3:0	929	990	1050	1143	1028	1061	1050	1121	1052	1071
3	17	1:5:0	1020	1098	1143	1245	1127	1132	1113	1217	1160	1155
3	22	1:5:0	1059	1122	1150	1287	1154	1166	1139	1225	1175	1176
4	25	1:4:1	1088	1177	1204	1340	1202	1255	1244	1295	1261	1264
4	37	1:4:1	1291	(1286)	1348	1479	1351	(1422)	(1320)	1518	1475	1497

[1]Removed at the end of the 34th week.
[2]Removed at the end of the 33rd week.
[3]Removed at the end of the 30th week.

TABLE NO. 3—AVERAGE DAILY GAINS PER STEER PER PERIOD

(Results expressed in pounds)

Period	No. of weeks	Ratio of hay to corn to oil meal	Maintenance Lot				
			Animal 653	Animal 650	Animal 656	Animal 658	Average
1	1- 5	1:1:0	1.97	1.57	1.97	0.34	1.46
2	8-13	1:3:0	0.05	0.12	0.07	0.00	0.00
3	17-22	1:5:0	0.12	0.05	0.10	0.14	0.04
4	25-37	1:4:1	1.73	2.11	0.47	0.57	1.22
Total	1-37		0.88	1.05	0.48	0.37	0.70
			One-third Feed Lot				
			Animal 667	Animal 666	Animal 669	Animal 662	Average
1	1- 5	1:1:0	1.69	2.51	1.97	2.14	2.08
2	8-13	1:3:0	1.93	1.33	1.31	1.98	1.64
3	17-22	1:5:0	1.40	0.55	1.29	1.26	1.12
4	25-37	1:4:1	1:57	1.87	1.15	0.81	1.35
Total	1-37		1.39	1.34	1.23	1.30	1.32
			Two-thirds Feed Lot				
			Animal 668	Animal 652[1]	Animal 665	Animal 657	Average
1	1: 5	1:1:0	2.51	3.03	3.37	2.57	2.87
2	8-13	1:3:0	1.71	2.24	1.57	1.83	1.84
3	17-22	1:5:0	1.64	1.50	1.02	1.74	1.48
4	25-37	1:4:1	2.23	1.56	1.58	1.53	1.72
Total	1-37		1.80	1.75	1.78	1.81	1.79
			Full Feed Lot				
			Animal 659[2]	Animal 663[3]	Animal 661	Animal 664	Average
1	1- 5	1:1:0	3.03	3.40	2.54	2.94	2.98
2	8-13	1:3:0	2.62	2.14	1.95	2.40	2.28
3	17-22	1:5:0	1.64	2.12	0.90	1.33	1.50
4	25-37	1:4:1	2.65	1.81	2.45	2.35	2.31
Total	1-37		2.29	2.13	1.98	2.10	2.13

[1]Removed at end of 34th week.
[2]Removed at end of 33rd week.
[3]Removed at end of 30th week.

TABLE 4—AMOUNT OF FEED CONSUMED PER POUND OF GAIN PER LOT PER PERIOD
(Results expressed in pounds)

Period	No. of wks.	Ratio of hay to corn to oil meal	Maintenance Lot			One-third Feed Lot			Two-thirds Feed Lot			Full Feed Lot		
			Clover hay	Ground corn	Oil meal	Clover hay	Ground corn	Oil meal	Clover hay	Ground corn	Oil meal	Clover hay	Ground corn	Oil meal
1	1- 5	1:1:0	3.74	3.74	....	3.79	3.79	....	3.58	3.58	....	4.19	4.19	....
2	8-13	1:3:0	......[2]	......[2]	....	2.29	6.85	....	2.86	8.58	....	2.83	8.49	....
3	17-22	1:5:0	32.52[1]	162.60[1]	....	1.98	9.88	....	2.11	10.53	....	2.35	11.74	....
4	25-37	1:4:1	1.33	5.30	1.33	1.72	6.88	1.72	1.72	6.88	1.72	1.53	6.13	1.53
Total	1-37		3.29	9.20	0.87	2.66	7.55	0.67	2.63	7.51	0.62	2.75	7.68	0.57

[1]One or more steers in lot lost in weight.
[2]Lot made no gain.

TABLE 5—DRY SUBSTANCE CONSUMED PER LOT PER POUND GAIN
(Results expressed in pounds)

Period	No. of weeks	Ratio of hay to corn to oil meal	Maintenance Lot	One-third Feed Lot	Two-thirds Feed Lot	Full Feed Lot
1	1- 5	1:2:0	6.53	6.61	6.25	7.33
2	8-13	1:3:0	......[1]	7.95	9.96	9.86
3	17-22	1:5.0	171.60	10.43	11.08	12.41
4	25-37	1:4:1	6.94	9.03	9.03	8.06
Average	1-37		11.67	9.51	9.40	9.63

TABLE 6—TOTAL DRY SUBSTANCE CONSUMED PER STEER PER POUND GAIN

(Results expressed in pounds)

Period	No. of weeks	Ratio of hay to corn to oil meal	Maintenance Lot Animal No. 653	Animal No.650	Animal No. 656	Animal No.658	One-third Feed Lot Animal No. 667	Animal No. 666	Animal No. 669	Animal No. 662
1	1-5	1:1:0	4.78	6.11	4.87	28.00	8.17	5.35	7.03	6.49
2	8-13	1:3:0	151.55	......[1]	110.91	......[2]	6.57	9.54	10.12	6.78
3	17-22	1:5:0	......[1]	155.14	77.57	50.23	8.05	20.30	9.38	9.86
4	25-37	1:4:1	5.66	4.73	14.94	12.36	8.44	6.77	9.82	14.28
Total	1-37		9.40	8.34	16.07	20.92	9.17	9.20	10.04	9.68

Period	No. of weeks	Ratio of hay to corn to oil meal	Two-thirds Feed Lot Animal No. 668	Animal No. 652	Animal No. 665	Animal No. 657	Full Feed Lot Animal No. 651	Animal No. 663	Animal No. 661	Animal No. 664
1	1- 5	1:1:0	7.21	5.74	5.37	7.08	7.38	6.02	8.71	7.60
2	8.13	1:3:0	10.61	7.78	11.85	10.38	8.27	9.35	12.06	10.25
3	17-22	1:5:0	9.70	9.91	16.47	10.23	11.67	7.64	20.16	15.64
4	25-37	1:4:1	7.47	9.14	9.84	10.39	7.27	8.22	8.05	8.62
Total	1-37		9.48	8.95	9.49	9.64	9.03	8.41	10.43	10.47

[1]Steer lost in weight.
[2]Steer made no gain.

TABLE 7—COEFFICIENTS OF DIGESTIBILITY OF DRY SUBSTANCE

Period	Maintenance Lot	One third Feed Lot	Two-thirds Feed Lot	Full Feed Lot
1	69.29	65.91	63.84	62.55
2	77.73	71.88	68.82	64.68
3	78.74	75.80	73.61	69.68
4[1]	79.56	76.90	75.04	76.01

[1]Includes only 25th to 30th week.

TABLE 8—COEFFICIENTS OF DIGESTIBILITY OF DRY SUBSTANCE IN PERIODS 3 and 4

	One-third Feed		Two-thirds Feed		Full Feed	
	Steer No. 666	Steer No. 669	Steer No. 652	Steer No. 665	Steer No. 663	Steer No. 661
Period 3	75.10	76.51	76.13	71.09	74.06	65.31
Period 4[1]	76.79	76.61	77.53	72.35	79.09	74.10

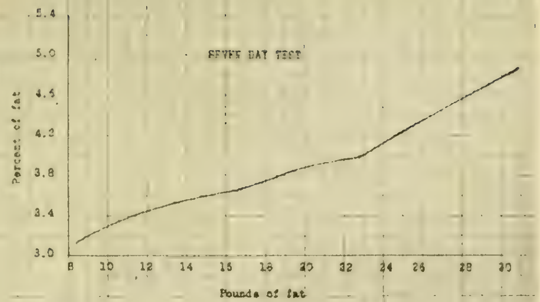
[1]25th to 37th week except in cases of those steers which were removed from the experiment before the 37th week.

A STUDY OF THE RELATIVE RELIABILITY OF OFFICIAL TESTS OF DAIRY COWS

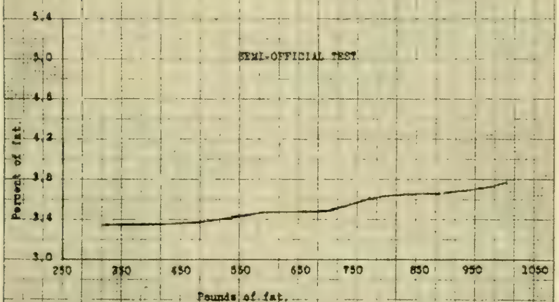
W. W. YAPP, UNIVERSITY OF ILLINOIS

To those who are familiar with the dairy industry, I need not point out that, during the past twenty years, there has been a significant increase in the United States, both in respect to the number of milch cows and to the amount of milk and butterfat produced. But out of all proportion to this increase has been the increase in advanced registry testing, or the conducting of official tests for ascertaining the milk and butterfat production of pure-bred cows. In the few moments which I have to speak I cannot even touch upon the extent of this increase or upon the factors which have tended to bring about this growth, but I must begin directly with the discussion of the relative reliability of these tests.

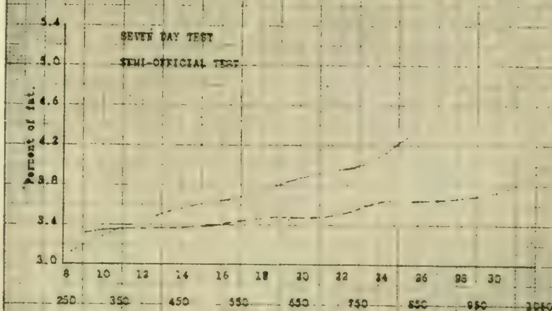
I shall not attempt to report on my findings except with regard to two tests, the seven-day test and the semi-official test. These tests as studied apply only to the Holstein-Friesian breed of dairy cattle. Briefly stated, the seven-day test is an official test, which means that the supervisor or tester weighs and tests the milk of each milking separately, being present at



Curve showing the relation of the amount of production to percentage of fat.



Curve showing the relation of the amount of production to percentage of fat.



Curve showing relation between seven day and semi-official tests.

each and every milking during the entire testing period. The semi-official, long-time test usually covers a yearly period. By semi-official test we mean one in which the percentage of fat in the milk is determined by an official test which covers a period of not less than two consecutive days each month. The approximate fat production for the month is found by multiplying the weight of milk which the owner supplies by the per cent of fat found during the period of official test. The total fat production for this period is the sum of these various monthly credits.

In making the comparisons between these two tests the records are taken from the Holstein-Friesian Advanced Register, the official publication of the organization. Only comparable records are considered. By comparable records is meant that the records, both seven-day and semi-official, must be made by the same cow during the same lactation period.

It is interesting to compare these tests with respect to the percentage of fat which each carries, keeping in mind that the same group of cows is considered in each case. Table 1 shows the relation of percentage of fat to amount of production for the seven-day test.

TABLE I—RELATION OF PERCENTAGE OF FAT TO AMOUNT OF PRODUCTION—SEVEN-DAY TEST

Class of Intervals # Fat	Frequency	Lbs. Milk	Per Cent Fat	Lbs. Fat
Under 9 # Fat	28	268.4	3.14	8.415
9.01-12.00	192	318.5	3.36	10.697
12.01-15.00	350	381.0	3.53	13.441
15.01-18.00	374	453.1	3.64	16.479
18.01-21.00	214	503.0	3.84	19.325
21.01-24.00	114	574.6	3.97	22.837
24.01-27.00	18	587.1	4.26	25.025
27.01-30.00	4	567.5	5.15	29.226

A study of Table No. 1 shows that low fat production is accompanied by a low fat percentage, whereas high fat production is secured to a considerable degree by a high fat test. If we disregard the last class, which has but four records from which to draw an average, we find that the difference in fat percentage between low and high production is 1.12 per cent. Compare with this the fat percentage found for the semi-official test of the same cows during the same lactation period.

TABLE II.—RELATION OF PERCENTAGE OF FAT TO AMOUNT OF PRODUCTION—SEMI-OFFICIAL TEST

Class Intervals # Fat	Frequency	Lbs. Milk	Ave. Per Cent Fat	Ave. Lbs. Fat
251- 350	83	9538.7	3.35	320.585
351- 450	349	12100.6	3.35	405.382
451- 550	410	14747.0	3.39	499.977
551- 650	270	17142.1	3.47	595.983
651- 750	122	19875.9	3.48	691.735
751- 850	35	21720.8	3.62	787.161
851- 950	16	24453.3	3.65	892.332
951-1050	9	26225.6	3.79	993.367
1051-1150	1	24612.8	4.53	1116.050

Omitting the last class in which but a single record occurs we find that cows which produce 320.59 pounds fat test, on the average, 31.35 per cent fat, whereas those cows which produce 993.32 pounds fat test, on the average, 3.79 per cent, a difference of but .44 of 1 per cent. This would seem to indicate that the semi-official test is more uniform with respect to percentage of fat both in low and in high production than the seven-day test.

Even more interesting and significant than the study of the relation of these two tests with respect to fat percentage is that of the correlation which exists between them. By using the standard method for calculating the correlation coefficient we find that the correlation which exists between seven-day and semi-official fat production is $.662 \pm .011$. This for many purposes would be regarded as a high degree of correlation, but it is not so regarded between two measurements of the same thing, namely the productive ability of a given group of cows. The correlation between seven-day semi-official milk production is $.658 \pm .011$, almost the same as the correlation found for fat production.

It would seem from these studies that the seven-day test is not a very dependable criterion by which to judge semi-official or yearly production.

THE INFLUENCE OF UTENSILS ON THE GERM CONTENT OF MILK

M. J. PRUCHA, UNIVERSITY OF ILLINOIS

In the crusade for sanitary milk supply, the efforts have been centered largely upon the production of milk with a small number of bacteria. Milk, as it passes from the milk glands of the cow to the final vessel in which it is sold, is exposed to numerous sources of contamination, and before sanitary milk production can be placed upon a rational basis it is necessary to have more definite information on the relative importance of the various sources of contamination.

With this in view the investigation on the utensils as a source of bacteria in milk has been undertaken by the Dairy Department at the University of Illinois. The investigation has shown that utensils, when cleaned in the ordinary manner, and not sterilized, add very large numbers of bacteria to the milk.

The extent of contamination of milk by the utensils is forcibly brought out by one of the experiments in this investigation.* In this experiment all the utensils were steamed for each milking during fourteen days and the samples were taken from the milk as it passed into the respective utensils. During the following two weeks the utensils were washed, but were not steamed, and samples were again taken. The results are summarized in the following table.

Utensils Sterile		Bacteria per cc.
Milk leaving barn	2,277	
Same milk, one hour later, bottled	3,875	
Utensils Not Sterile		
Increase due to 3 pails	57,077	
Increase due to strainer	15,353	
Increase due to clarifier	172,763	
Increase due to cooler	19,841	
Increase due to bottler	247,611	
Total in bottled milk one hour old		515,200

In this experiment only 2,277 bacteria were due to all the barn conditions and over half a million bacteria were introduced into the milk by washed utensils. All other experiments lead to the same conclusion, namely, that the utensils as cleaned and cared for by the methods in vogue are a very important source of bacteria in the milk.

*The results of the entire investigation are published in a bulletin by the Agriculture Experiment Station at the University of Illinois.

Papers on Botany

AN ECOLOGICAL SURVEY OF THE VEGETATION OF THE ILLINOIS PRAIRIES—A PRELIMINARY REPORT

Homer C. Sampson, University of Chicago

During the summer of 1915 the writer made a study of the associations of prairie plants occurring upon the relic virgin prairie tracts throughout the state. The work was conducted through the aid of the State Natural History Survey, and under the direction of Dr. Henry C. Cowles and Dr. George D. Fuller. The locations of the areas studied were obtained through ahe aid and courtesy of the county surveyors. Among the tracts visited and found to be in a sufficiently undisturbed condition to warrant further study are the flood plain and sand prairies along the Mississippi River between Ebner and Savanna and at Hanover, sand prairies in the valley of the Green River in Bureau and Henry counties, morainic sloughs near Lacon and Camp Grove in Marshall county, numerous prairies on the outskirts of Chicago on the old lake bed of Lake Chicago, and a few small areas in Jasper and Clay counties. Old fence-rows and railway rights-of-way were also considered after the survey had advanced sufficiently to indicate their limitations. A detailed account of the locations of these prairies and other less promising ones will appear in a later publication.

At the time of this report the data at hand seem sufficient to allow the formulation of the following tentative conclusions:

1. The virgin prairies of Illinois exhibit definite associations of prairie plants. These associations are related in a definite way to definite types of topography and soil conditions which range all the way from such pioneer habitats as clay, sand and swamps, to the well-drained soil of the upland prairies.

2. The development of the physiography of these pioneer habitats is followed by dynamic successions of the plant associations. The associations in these successions differ in each particular case according to the initial habitat, but in all cases they ultimately lead to a common type of climax prairie.

3. Andropogon furcatus is the most abundant grass of this climax prairie, and usually occupies more than 80 per cent of the total area of the association which it represents. This fact suggests that Andropogon furcatus is the climax grass of the Illinois prairies.

4. In their order from pioneer to climax, the most important associations of the hydrarch successions are Scirpus fluviatilis, Carex vesicaria, Spartina Michauxiana, Calamagrostis canadensis, Panicum virgatum and Andropogon furcatus. The most important associations of the xerarch succession on sand are Panicum pseudopubescens, Andropogon scoparius and Andropogon furcatus; on clay, Andropogon scoparius and Andropogon furcatus.

5. During long continued grazing the Andropogon and Panicum virgatum associations are displaced by a blue grass (Poa pratensis) sod. Each of the other associations is likewise displaced by more or less definite types of pasture plants.

6. Owing to the numerous diverse types of disturbance by man, the associations of prairie plants on railway rights-of-way are unnatural and in certain respects do not agree with those found on the undisturbed virgin areas. Relic patches of these virgin associations on these rights-of-way are, however, still abundant enough to give a general picture of the original prairies. Data collected from this point of view show that most of the prairie area of the older glaciated regions of the state had reached the Andropogon furcatus stage before the coming of the plowman, while much of the prairie area of the Wisconsin glaciation was dominated by Spartina Michauxiana, Calamagrostis canadensis and Panicum virgatum, according to the development of the drainage conditions. This conclusion is further substantiated by the word of the older inhabitants who saw these prairies in all their original grandeur.

7. In a general way the trend of the associations on the black-soil clay prairies follows the changes in the moisture content of the soil as the physiography of the regions develops. In the sand prairies transpiration, stability of the soil and probably nutrition are also factors of prime importance.

Fig. 1. Russula foetentula Pk.

Fig. 2. Russula foetentula attached to mycorrhizal roots of Quercus alba

8. The data also support the theory that many of the black-soil prairies of Illinois originated from glacial lakes and swamps and have existed as prairies since glacial times.

The work is still under way and it is hoped that a detailed report will appear in 1917. The final report will be published as a Bulletin of the State Natural History Survey.

SOME INTERESTING MUSHROOMS OF CHAMPAIGN COUNTY

W. B. McDougall, University of Illinois

Among the mushrooms collected in the vicinity of Urbana, Illinois, during the past two years there are three to which especial interest attaches, for a different reason in each case. The first of these is Russula foetentula Pk. (Fig. 1). This species is easily recognized by its reddish yellow, viscid pileus which is conspicuously striate at the margin, and from its odor, which is that of bitter almonds. Other distinguishing features are the pale yellow color of the spores and reddish brown stains at the base of the stem. R. foetentula was described from New York by Peck in 1906 and seems not to have been found commonly elsewhere. This may be due to the fact that it is rather easily mistaken for R. foetens Fr., to which it is closely related. It is a very distinct species, however, differing from R. foetens in having the odor much less pronounced, in the closer gills and in the reddish stain at the base of the stem, as well as in the color of the spores which in R. foetens are white.

The interesting thing about this mushroom is that it habitually produces mycorrhizas on the white oak (Quercus alba) trees in the "forestry," an artificial woodlot at the University of Illinois. R. foetentula has not previously been reported as a mycorrhiza former. In fact, only one species of this very large genus, and that an undescribed species, has been so reported.[1] R. foetentula occurs quite abundantly during favorable weather among the white oaks of the forestry, from the middle of June to the end of August, and I have been able to demonstrate repeatedly its attachment to the mycorrhizal roots (Fig. 2).

The second mushroom to which especial interest attaches is Hypholoma lacrymabundum Fr. (Fig. 3). This mushroom is reported in nearly all mushroom books as not common and its edibility unknown. It is reported from the Chicago region by Moffatt, but the frequency of its occurrence there is not noted.

The plant is not difficult to recognize. The cap is light yellowish, but becomes darker with age and may become stained with black, especially when the spores are washed on to it by rains. The surface is more or less covered with silky threads and usually has irregularly radiating wrinkles. The gills are attached to the stem and in the mature specimens are spotted with black and brown due to the irregular maturing of the spores. The appearance of the gills reminds one of some of the dark colored Pholiotas such as P. squarrosa. H. lacrymabundum gets its specific name, meaning weeping or filled with tears, from the fact that in the morning or in damp weather the gills usually have minute drops of water along their edges. The spores are black but with a purple tinge, and the stem is the same color as the cap and usually more or less loose scaly except at the top.

The plant is by no means uncommon in this locality. It was found first under a bridge within the city of Urbana, but was later found in great abundance north of the city. It grows either singly or in clusters, as many as fifteen having been found in a single cluster.

I ate freely of this mushroom during the past summer, and, while I do not consider it among the best of edible species, it is not dangerous and it compares favorably with other species of Hypholoma. It may be looked for from August to October.

The third mushroom to which I wish to call attention is Stropharia epimyces (Peck) Atk. (Figs. 4 and 5.) This is the most interesting of all because it is parasitic on another

Fig. 3. Hypholoma lacrymabundum Fr.

mushroom. It is considered rare, but it has occurred very abundantly in several localities north of Urbana during the past two seasons. t

The plant was first described by Peck in 1884 as Panaeolus epimyces.[2] It was redescribed by Atkinson in 1902[3], and again in 1907,[4] and placed in the genus Stropharia because of the purplish tinge of the spores and the presence of a ring on the stem. Both of these characters are evident in the specimens collected about Urbana and these specimens seem to be nearer to the genus Stropharia than to Panaeolus, although the ring is very slight and is near the base of the stem. It is the same type of ring as that which is formed in the common inky cap mushroom, Coprinus atramentarius. A study of the development of the fruit body, such as I hope to be able to make from material which I now have, will undoubtedly throw considerable light upon the relationships of the plant.

S. epimyces occurs either singly or in clusters. Figure 6 shows an extra large cluster. The plant grows from 3 to 8 cm. high and the cap is from 2 to 6 cm. broad. The cap is dingy white in color and somewhat floccose scaly. The gills are attached to the stem and are dark brown. The spores are nearly black but have a slight purplish tinge. No one would fail to recognize this mushroom after once seeing a picture of it.

The identification of the host plant was first published by Atkinson in 1902,[5] as Coprinus atramentarius. In 1905 a second host, Coprinus comatus, was added by Miss Sherman,[6] All specimens collected at Urbana have been on the shaggy mane mushroom, Coprinus comatus. Fig. 7 shows an interesting series. At the left is an unparasitized specimen of Coprinus comatus. Next to it is a pair of specimens deformed by the parasite which is present but has not developed fruit bodies. The third specimen has two partly developed fruit bodies of the parasite on it, and finally there is shown the fully matured parasite on a host so badly deformed as to be scarcely recognizable.

[1]McDougall, W. B., Am. Journ. Bot. 1:51, 1914.
[2]35th Rept. N. Y. State Mus. Nat. Hist. 133, 1884.
[3]Jour. Myc. 8:118, 1902.
[4]Plant World, 10:121, 1907.
[5]Jour. Mycol. 8:118, 1902.
[6]Jour. Mycol. 11:167, 1905.

Stropharia epimyces is edible and the flavor is the same as that of the host on which it grows. It is, therefore, a boon to those mycophagists who prefer their mushrooms plain fried and at the same time are partial to the flavor of Coprinus comatus, since C. comatus is not firm enough to fry nicely while S. epimyces is.

PECULIAR PLANT DISTRIBUTIONS

H. S. Pepoon, M.D.

The author in the last few years has made an extensive study of the Floras of Jo Daviess, Fulton and Cook counties, Illinois, and upon the results of his observations in these counties the following notes are based. During these plant explorations 980 species were found in the first named county, 1000 in Fulton, and 1800 in Cook and adjacent parts of Lake counties, Indiana and Illinois. A "few years" may be better expressed by the term a half life time, for Jo Daviess is the home of his youth, Fulton of his young manhood and Cook of more mature years.

During this period, stretching back 40 years, some 2500 square miles have been carefully explored, 1,000 miles of tramping undertaken and countless thousands of individuals have come under observation. The topographic features have included the bed and border lands of *Glacial Lake Chicago* with its marshes, prairies, dunes and moraines, the rolling uplands of the *Upper Illinoisan* stage of the glacial period and the *Driftless area* of Jo Daviess with its gorges, cliffs, bottom lands and elevated highlands and erosion "mounds." The accompanying map shows the relative position of these regions and other data.

It may be remarked in a generalization that the Jo Daviess area has many boreal forms, the Cook county a great mingling of boreal and temperate species, and Fulton shows many that proclaim a warmer predeliction. Possibly 60 per cent of the plants are common to all the counties named. As might be expected, weeds are far more numerous in individuals and species in Cook county, for weeds are primarily plant-tramps that utilize to the limit the great trunk railways.

Fig. 4. Stropharia epimyces (Pk.) Atk.

Some 54 examples of peculiar distribution are here cited with reasonable explanations of the same where explanation is apparent. The author admits that some of these explanations are possibly open to criticism and invites the same with the hope expressed that it partake of a friendly helpful nature. These examples are given in the order of their natural sequence from lower to higher forms. In a great majority of the examples named the stations are unique, in that the plants were found there and there only in the three counties. This very isolation renders the cases of distribution more interesting, and at the same time more difficult of explanation. To avoid continual repetition, the letters appended refer to the proposed explanations given in the conclusion and summary.

1. *Pellaea atropurpurea,* the rock brake, is found in the deep stone "cuts" of the Illinois Central railway west of Warren, probably five miles from any natural stations which lie south and west. Also in similar cuttings southeast of Freeport, 30 miles distant and nearly 40 miles from natural outcrops. N. W. of center of Distribution (D. C? or A?)

2. *Woodsia obtusa,* in the famous rock cut of the St. Paul railway, north of Warren. One clump only. No other stations known for the species in Jo Daviess. N. W. of center (D).

3. *Botrychium obliquum,* one plant on the Niagara limestone summit of Benton Mound. No others ever found nearer than 10 miles. Only the one station ever discovered in Jo Daviess. (G).

4. *Azolla Caroliniana,* exceedingly abundant along Liverpool road in Illinois River bottoms of E. Fulton, the only station where the plant has ever been seen, in all of the author's botanical tramps. (G).

5. *Tripsacum dactyloides,* on an alluvial border below Seville, Fulton county, the only station; along the northern limit of range. (C).

6. *Acorus Calamus,* Sweet Flag, in isolated and far separated *patches* here and there in all three counties. The writer hazards the theory that this peculiar distribution, entirely absent in countless suitable places, is due in large part to Indian planting. (B).

7. *Wolffia Columbiana,* exceedingly abundant years ago north of Clarke, Indiana, but absent elsewhere in all three areas. (G).

8. *Commelina Virginiana,* on the dry dune sand S. E. of Clarke, Indiana, and on the sand bluff of the Mississippi river in Jo Daviess. (See Gray 7th Ed.) (G. or I.)

9. *Allium stellatum,* one station on C. B. & Q. railway, sand prairie, Jo Daviess. (A).

10. *Camassia,* abundant in Cook; in one or two stations in Jo Daviess. A plant much used by the Indians as a food plant. (B. and A.)

11. *Clintonia borealis,* in two tamarack swamps in Lake county, Indiana. A numerous colony in each. Plainly an extension from the northeast. (C).

12. *Trillium sessile,* in woods south of Naperville and on Salt Fork of Des Plaines river. A very rare or over-looked species. Never have seen the plant in its place of growth. (G).

13. *Cypripedium hirsutum,* excessively abundant, formerly in Lake county, Indiana, equally common now in Southwest Michigan. Found in two very peculiar habitats in Jo Daviess, one on a dry wooded hillside, and the other on the crown of a limestone cliff, four miles distant from the first station. (G? or I.)

14. *Orchis spectabilis,* very rare in all counties, except in one locality in Fulton where a half acre was found absolutely a colored sheet of bloom. Probably a thousand plants here. Certainly some condition was exceedingly favorable to account for the number and vigor of the plants. (G).

15. *Habenaria leucophaea.* Until five years ago, the rarest orchid in the writer's experience, and then two finds, one in Cook and one in Jo Daviess, disabused his mind about this rarity, but puzzled him the more as to why they were there. The Cook county station was on the flat, moist prairie of a vacant property, near Elston avenue, Chicago, where many score of plants grew. The Jo Daviess station was in two grassy swales on the right of way of the I. C., where the plants flourished by hundreds. Before these finds, two plants had been seen: one on a hillside near No. 13, and one on Platte Island in Platte River, Neb., near Fremont. (E).

16. *Pogonia trianthophora* has been found in five stations during all my many years of collecting. Four are far separated clumps in southwest Michigan, the fifth three plants in a Jo Daviess woodland. (G).

17. *Calopogon*. Abundant southeast of Chicago. Was found as a single plant on a bluff-crown of Jo Daviess. A remarkable habitat for the one solitary example. (I).

18. *Arethusa*. Found in a single locality: southeast of Chicago. A dozen plants in a cranberry bog. (G).

19. *Epipactus pubescens*. A single colony a rod square in a dry oak wood in Jo Daviess. Vigorous, but very strange to its surroundings. This plant is frequent in southwest Michigan, and northeast. Western limit. (G).

20. *Corallorrhiza maculata*. In a dense Jo Daviess woodland; the only station the plant has been seen in outside of Michigan and Canada. Several plants. (G).

21. *Aplectrum hyemale*. Two plants. Twelve miles apart in Jo Daviess, one on a Mound Crest, the other on a slope, both in woods. A third station of two plants under a Thuja on the bluff at Highland Park, north of Chicago. Common in southwest Michigan. (G).

22. *Salix coactilis*. A few plants on the Du Page river at Warrenville, determined by Prof. Fernald. Maine is its home. (I).

23. *Populus heterophylla*. Quite a colony north of Port Chesterton, Ind., in woods. Associated with the three common species of Populus. Far to the north of its center. Badly diseased and seemingly in a dying condition. (C).

24. *Carya Illinoensis*. A tree 3 feet in diameter and 80 feet in height, on the Mississippi river bottoms near lower Jo Daviess. Copiously nut-bearing and perfectly thrifty. (B. C.)

25. *Betula alba papyrifera*. Summit of Benton Mound, 1100 feet altitude, Jo Daviess, on Niagara limestone. Many thrifty trees. From Jo Daviess north along the Mississippi river bluffs. (C).

26. *Fagus grandiflora.* A clump of 5 trees in the midst of an oak wood, northeast of Edgebrook. No other known trees within 30 miles. Perfectly at home. (B. C.)

27. *Quercus Prinus.* On the rocky banks of Apple river, Jo Daviess county. Several trees and far from its home center. (I).

28. *Morus rubra.* Two trees in Apple river gorge near the last. None other ever found in the county. (C). Common in Fulton.

29. *Oxybaphus floribundus, albidus, hirsutus.* Common along the Great Western railway, west of Stockton. Far from home. (A).

30. *Nelumbo lutea.* In the great Calumet, at Clark, Ind. Many plants, but not in vigorous condition. Excessively common below Peoria. This is the plant, that wherever found, is claimed by the natives "to grow in only *one* other place in the world." (B).

31. *Cristatella Jamesii.* Very abundant on the sand dune bordering sand prairie, Jo Daviess county. Not in Gray, 7th Edition. From the far west. (I-B?).

32. *Ribes triste.* A single bush in the center of a dense wet wood northwest of Chicago. Far northern and northeastern. (B-R).

33. *Prunus angustifolia Watsoni.* Two fine thickets on the L. S. & M. S. railway, southeast of Chicago. (A. B.)

34. *P. hortulana.* A single tree. Apparently native, on margin of Little Calumet Valley, near Dune Park. Very thrifty. (B-A.)

35. *Gymnocladus.* A fine clump on a gravel knoll near the Illinois river, north of Havana, in Fulton county. A few fine trees in Apple river gorge, Jo Daviess county. Two similar clumps were found in Van Buren county, Michigan. A strange and exceedingly rare distribution. A single tree found south of Red Wing, Minnesota. (B. or possibly A).

36. *Hosackia Americana.* Abundant along C. B. & Q. railway in Jo Daviess, western. (A).

Fig. 5. Stropharia epimyces. The ring can be seen near the base of the stem

37. *Callirhoe triangulata.* A colony near N. Clark street, Chicago, on sand ridge. A thriving colony on Liverpool Island, Fulton County. Abundant on Sand Prairie, Jo Daviess county. (G.-B.)

38. *Viola striata,* on the almost vertical face of a wet limestone cliff of the Mississippi river below Portage, Jo Daviess. So abundant in this strange habitat as to tint the cliff face; a marvelous place for a violet. (I).

39. *Viola pedata bicolor.* On a bold, gravel bluff in the woods, along Spoon river, Fulton county, growing over a space of fifty feet by a hundred. Never seen by author elsewhere in any of his rambles. (G?-H.)

40. *Cuphea petiolata.* One plant. Illinois valley above Havana, Fulton county (G).

41. *Lythrum Salicaria.* Wabash railway. One plant. Eastern. (A.)

42. *Oenothera speciosa.* Two plants. Along Belt railway, Chicago, western. (A.)

43. *O. serrulata.* One vigorous clump on dry prairie west of Chicago, one clump in Jo Daviess county. (B.)

44. *Vitis Labrusca.* In occasional groups through the Dunes, southeast of Chicago, freely fruiting. Eastern. (B-C?)

45. *Chimaphila umbellata.* A large clump on summit of Benton Mound, near No. 25. Abundant in Southwest Michigan and East and North. (G.)

46. *Primula Mistassinica.* Exceedingly abundant on wet cliff on Apple river, Jo Daviess county, near Junction of Branches. Far northern. (C).

47. *Ipomoea pandurata.* Common along Mississippi river on slope between I. C. railway and water near Portage, Jo Daviess county. Found once in Fulton on Illinois river. (B.)

48. *Salvia lanceafolia.* Great Western railway, near Elizabeth, Jo Daviess county. One clump. (A.)

49. *Castilleja sessiliflora.* Great numbers on the sand moor north of Waukegan. A western species. (B.)

50. *Martynia Louisiana.* Several plants in alluvium, along a road in Fulton county. (B.)

51. *Diodia teres.* Sand bluff of Mississippi river. Jo Daviess county. Common. (B.)

52. *Cucurbita foetidissima.* One plant on Wabash railway, near Chicago, existing for years. Root eight inches thick. (A.)

53. *Lepachys columnaris.* Several near No. 48. (A).

54. *Grindelia squarrosa.* Along most trunk railways. A patch over one acre in Van Buren county, Mich., now about eight years established. (A.)

Reviewing these fifty-four examples and keeping in mind their centers of greatest abundance and most normal growth conditions, the author proposes the following explanations of their present isolated or peculiar distribution as to region and particular habitat.

There can be but little question but that examples 29, 33, 36, 41, 42, 48, 52, 53, and 54 are representatives of the great host of species that are being scattered far and wide by trunk or transcontinental railway lines, the traveling seeds falling from freight or stock cars while in transit. While many such remain railway plants, others finding congenial habitats gradually expand their growing areas. None of the plants named can rightfully be classed as weeds. (A.)

It has always appeared to the author that the exceedingly peculiar distribution of the Coffee-bean, Lotus, Calamus, and some other plants not concerned in our present article, might be the result of accidental or intentional aboriginal plantings. Practically all such species had an economic value to the Indian, and it is as consistent to adopt this view as it would be in coming days to explain the presence of many deciduous fruits to the agency of the white race. In the case of the Fox Grape, all Indiana stations lie near the Great Sauk Trail which is known to have been the path of Iroquois marauders, and it seems perfectly reasonable to adopt this explanation for the isolated distribution. There are thousands of suitable localities for the Lotus in Illinois, but the actual stations can

Fig. 6. Cluster of Stropharia epimyces.

almost be counted on one hand. It does not appear reasonable to explain by any survival theory when the one here stated is so tenable. (B.)

A few of the species named are plainly the outposts of distribution, although it is very probable that in preglacial days, this distribution might have been far more extensive. The Canoe Birch and Mistassinican Primrose are good examples growing as they do on rocks untouched by the great ice cap, and ending abruptly in Jo Daviess with the advent of the drift. Such species are 1, 11, 24, 23, 24, 26, 28, 44, 46. (C).

The deep rock cuts of the Illinois Central railway furnish an artificial habitat closely simulating the natural cliffs, and it is easy to understand how Pellaea and Woodsia would flourish in such surroundings when once established. The question, however, is not so easy of solution, for how did the spores reach the cut east of Freeport nearly forty miles from natural growth? (D. C or A?).

Doubtless a few examples representing all that are left of an original host of plants that through the advance of cultivation and consequent destructions of suitable places of growth, have finally diminished to their present inconsiderable proportions. Such are 10, 14, 15. (E.)

A few are plainly a relic of the ice age, having been pushed southward by the ice and on its retreat scattered remnants persisted here and there. This is particularly the case about the head of Lake Michigan, and may account for such plants as numbers 13, 16, 18. (F.)

The majority of the balance may be considered remnants or survivals of a very much more extended flora that from many varied causes have been exterminated, and these last representatives, leading an uncertain existence until they too disappear, and the species vanish from such localities forever. The very peculiar isolated cases of the rattlesnake plantain, the pipsissewa and the coral root in the Jo Daviess flora may be such. Here it is highly probable the erosive agencies of flood and ice have carried to destruction the intervening stations, so that the isolation becomes much more pronounced. It may be the Cristatella comes here, but candidly no theory seems to fit it exactly. Far from transportation lines, in a station so removed as to be unnoticed in Gray, it offers a puzzle in distribution. (A.)

A few like the last named and the salix are an uncertain problem. (H.)

Finally one or two seem to have actually adopted a new habitat as a place of safety in the struggle for existence. Notably is this so with *Viola striata,* and its remarkable home on the wet cliffs of the Mississippi river bluff. Luxuriant to a degree and absolutely safe from extermination, it shows how survival may be brought about by change of habit. (I.)

Summarizing the causes of peculiar or isolated distribution we have,

A. Resulting from railway traffic and other commercial agents.

B. Aboriginal plantings by the Indians for food or other purposes.

C. Extension out-posts of floras with growth centers far removed.

D. Production of artificial habitats resembling in essentials the natural.

E. Destruction by cultivation, of most of the suitable habitats, isolated stations remaining.

F. Results of the glacial ice extension and retreat.

G. Survivals in the struggle for existence.

H. Uncertain.

I. Acquirements of new habitats by change in habits of growth.

Fig. 7. Coprinus comatus and Stropharia epimyces. See explanation in text.


Driftless
Jo Daviess Co.
Iowan
Lake Co.
Lake Michigan
Cook Co.
Rock River
Valparaiso
Moraine
Wisconsin
Upper Illinoisan
Fulton Co.
Shelbyville
Illinois River
Mississippi River
Middle Illinoisan
Moraine
Wabash River
Kaskaskia River
Lower Illinoisan
Map
Showing relative positions of
Cook, Fulton and Jo Daviess Counties
and
Relation to the Drift Zones
Limit of Ice
Unglaciated
Ohio River
42
41°
40°30'
40°
39°
38°
37°
91°
90°
89°
88°
Cook
Fulton
Jo Daviess
Elevation
600°
750° – 450°
1310° – 600°
Area
1100
870 Sq. Mi.
590 Sq. Mi.
Topography
Flat to undulating
Rolling
Very uneven
Forest
Less than 5%
40%
85%

CYTOLOGICAL PHENOMENA CONNECTED WITH SPERMATOGENESIS IN LIVERWORTS AND MOSSES

William L. Woodburn, Northwestern University

The liverworts and mosses (Bryophytes) are, for the most part, land plants which, however, complete a certain part of their life history under aquatic conditions. Very distinct changes in protoplasmic structure occur during the adaptation to the aquatic condition. Cells once non-motile and stationary, which are adapted to life and growth in an approximately fixed position, change to form and structure suitable to a very actively motile existence. These changes occur not in tissues or organs as a whole, in which case the cells or protoplasts might function en masse, but separately and co-ordinately in individual cells. Consequently the history of one of these cells is the approximate parallel of the history of any other similar cell.

The cytological phenomena, which will be under brief discussion in this paper, occur in each individual of one particular cell generation of the male sexual organ, the antheridium. This generation is the one in which each cell, when mature, constitutes a male sexual cell or gamete, commonly known as a spermatozoid or sperm. In order that it may function in the life history of the plant bearing it, the sperm finds and unites with the female sexual cell known as the egg or egg cell. To reach the egg the sperm must traverse a longer or shorter distance through an aquatic medium. This medium is supplied at more or less irregular intervals by rain and dew, or standing or flowing surface water. Our discussion concerns the changes occurring in the sperm cell which result in an admirable adaptation to the actively motile life which the sperm leads at this stage in the plant's life history. Although of much consequence, in fact, of absolute importance and necessity, the period of motility lasts but a very short time.

It might be well first to describe and locate the cells which give rise to the sperms. At certain places on the plant are formed multicellular globular bodies, just large enough to be detected by the unaided eye, known as the antherida. Each of these develops by growth and cell division from a single cell of the plant body. When near maturity each antheridium consists of a more or less globular mass of cubical cells, surrounded by a wall layer and united with the main body of the plant by a relatively short thick stalk. In the majority of the liverworts, at least, if not also in the mosses, the protoplast of each cubical cell gives rise by oblique division to two cells which when viewed from one side present a triangular outline. The two triangular protoplasts, Allen of Wisconsin has termed androcytes. Each androcyte becomes transformed into a sperm. Hence two sperms are eventually developed from each of the cubical cells. The occurrence of the last division in an oblique plane seems at least not so constant and prominent in the mosses as in the liverworts.

The protoplast, or organized protoplasm of one of these cubical cells, consists of a nucleus and cytoplasm. The outer boundary of the cytoplasm next to the cell wall forms a very delicate membrane, the plasma membrane. The remainder of the cytoplasm is more or less finely granular or lumpy when fixed and stained. Allen, however, finds in one of the mosses, Polytrichum, a certain part of the cytoplasm, the kinoplasm, organized into definite granular plates or membranes. The individual granules of the plates he calls kinetosomes. These kinoplasmic plates are present in the resting stage of the cell and seem to actively function in spindle formation as the cell prepares to divide.

The nucleus of this cubical cell, or androcyte mother cell, is spherical and sharply delimited by a distinct membrane, the nuclear membrane. The most prominent content of the nucleus is chromatin material variously arranged. Either a very distinct densely staining nucleolus may be present with surrounding chromatin granules in a more or less clearly defined, often sparse net work, or the chromatic material may be almost entirely included in one densely staining central nucleolar like mass. It seems quite evident that during a certain prophase of division whether a distinct nucleolus may be observed or not, the chromatin becomes largely collected into a mass in the center of the nuclear cavity. This mass, sometimes presenting an irregular, sometimes a smooth outline, is resolved into a more or less closely wound or irregularly gathered spireme. From this spireme the chromosomes are differentiated. Six chromosomes have been counted in the dividing spermatogenous cells of Mnium and Polytrichum, two common mosses, six is probably the number in Blasia and Porella two of the liverworts, while three other liverworts, Ricca, Marchantia and Fegatella have eight chromosomes each.

The androcyte, that is the cell destined to be transformed into the sperm, whether it is triangular in outline as the result of an oblique division or not, is constructed on the same general plan as the androcyte mother-cell just described. We find a definitely organized protoplast consisting of a nucleus and cytoplasm, the latter bounded apparently by a very delicate plasma membrane. Somewhat conflicting reports have been made recently as to the nature of the processes occuring as this androcyte becomes transformed into the mature sperm. In addition to the presence of nucleus and cytoplasm, there is quite general agreement as to the early appearance somewhere within the cytoplasm of a conspicuous dark staining body, the blepharoplast. The origin and nature of this body is as yet a matter of dispute. Whether it functions in the growth processes of the cilia or has to do with the change in form of the androcyte, or possesses other entirely distinct functions, it certainly forms the base of attachment of the cilia.

Briefly the transformation of the androcyte as the writer has observed it in Mnium, one of the common mosses, is as follows: (I find practically similar processes occurring in Marchantia, Blasia, Porella and Fegatella.) The protoplast of the androcyte rounds off slightly from the cell wall. The blepharoplast appears in the cytoplasm near the plasma membrane apparently as a cytoplasmic differentiation in the androcyte in which it is to function. The blepharoplast grows as a more or less radially flattened band in a course closely applied to the plasma membrane. The nucleus becomes closely applied to the blepharoplast, the chromatin network and nucleolus, if the latter is present, changing meanwhile in structure so that eventually the entire nucleus stains quite homogeneously. The nucleus lengthens parallel with and becomes more and more closely applied to the blepharoplast, so that the two form first a crescent and then a coil of one or two turns. The development of the blepharoplast precedes the change in form of the nucleus. During this process the nucleus and cytoplasm do not seem to be sharply separated by the nuclear membrane, but there are indications of diffusion from one to the other. The blepharoplast and nucleus continue to lengthen and fuse more closely, at last becoming indistinguishable, and eventually forming a long slender coiled almost filiform band or cord pointed at both extremities. The blepharoplast may be seen protruding for a short distance as a delicate filiform thread from one extremity of the sperm which we may call the anterior end. Attached near the tip of the blepharoplast are two long very delicate cilia. A vesicle, of granular cytoplasm and perhaps some nuclear material, within the coiled body of the sperm, disappears as the sperm reaches maturity, doubtless being absorbed by the main body or used up in protoplasmic activity, perhaps both.

To secure a common answer to the question of the origin and nature of the blepharoplast seems quite difficult. Two investigators, Ikeno and Bolleter, have described the blepharoplast as originating in the nucleus, and passing out into the cytoplasm through the nuclear membrane in the following manner. Prior to the last division of the spermatogenous tissue in the androcyte mother cell referred to above, a body separates from the chromatin structure and passes through the nuclear membrane into the cytoplasm. Here it divides and the two daughter bodies move to opposite sides of the nucleus and function as centrosome like bodies during spindle formation and the division of the nucleus. Each of these two daughter bodies persists in its respective cell, or androcyte, and functions as the blepharoplast. The figures of Ikeno and Bolleter scarcely present convincing evidence that any particular body which is first shown within the nucleus is identical with the particular body later seen outside the nucleus.

Others have described the appearance of the centrosome like bodies at the poles of the last division and the persistence of these bodies, each one in its respective androcyte, where it functions as a blepharoplast. Still others report centrosome like bodies during the last as well as earlier divisions of the antheridium, but fail to discover genetic continuity of these bodies from one cell generation to the next.

These polar bodies, according to the writer's observation, are more frequently found during the last division of the spermatogenous tissue, but even then seem to disappear during the telophase. Miss Black agrees with the writer in believing that the blepharoplast originates as a sharply differentiated cytoplasmic body in the androcyte in which it is to function and not from a previously formed polar or centrosome like body.

Wilson, writing in 1911, describes three distinct structures, originating from the nucleolus in the androcyte. One division results in the separation from the nucleolus of bodies which pass through the nuclear membrane into the cytoplasm, where they are resolved first into rod-like structures and then built into a more or less hollow spherical structure, termed a limosphere. The second division separates the nucleolus into two parts, one of which forms an accessory body and the other becomes the blepharoplast. The function of the blepharoplast has been described. The accessory body, doubtless similar to the Nebenkörper of Ilkeno, and the limosphere perhaps become part of the vesicle.

It seems safe to make the following statements referring in general to the liverworts and mosses:

The slender, flexible, more or less coiled bi-cilate sperm represents the metamorphosed protoplast of the androcyte.

In the androcyte two distinct parts are distinguishable, the nucleus and the cytoplasm.

In the sperm, besides the main body, or nuclear portion, which stains densely and homogenously and certainly contains the chromatin, there are present two cilia and a slender thread, the blepharoplast connecting these with the main body.

A more or less clearly defined vesicle, which contains remains of the cytoplasm, disappears as the sperm approaches maturity.

During the last as well as the earlier divisions of the spermatogenous tissue polar bodies are often present.

The facts recently brought to light leads the writer to venture also the following statements:

1. There is not at present satisfactory evidence that true centrosomes occur in the spermatogenous tissue of the Bryophytes.

2. Polar bodies, which often occur, do not seem to be identical with the blepharoplasts.

3. There is strong evidence, on the other hand, that the blepharoplast is of cytoplasmic origin.

4. It seems extremely doubtful if the various structures termed respectively "limosphere," "nebenkörper," and "kinoplasmic plates" occur regularly and constantly in the majority of the members of the Byrophytles.

5. In the observation and description of protoplasmic phenomena in this particular field it is not only wise, but quite necessary to bear in mind the small size of the cells, the dense protoplasmic contents with relatively little cell and nuclear sap, resulting in slow and difficult penetration of the killing fluids, and especially the extreme plasticity of the cells during this period of marked and rapid transformation of the androcyte into the mature and actively motile sperm.

TWO LEAF-FUNGI OF CYCLAMEN

William Trelease, University of Illinois

An inspection of any of the host lists for parasitic fungi shows that the florists' cyclamen in its many forms is remarkably free from such parasites, and one is always surprised if he finds disease or mutilated plants of any of the varieties under ordinarily good conditions of greenhouse treatment, though flower and leaf monstrosities are not infrequent. The principal diseases of the cyclamen are due to nematode root or tuber injuries and an associated rather obscure bacterial rot, and to attacks of *Thielavia* or *Atractium*. Few flower-inhabiting fungi have ever been observed on cyclamen; *Ascochyta cyclaminis* with the pycnidial *Septoria corollae*, and the conidial form of *Sclerotinia*, *Botrytis cinerea*. On the leaves scarcely more parasites have been found: *Septoria cyclaminis*, *Phyllosticta cyclaminis*, and *P. cyclaminella*, a *Glomerella* referred to the same species as that causing bitter rot of the apple, *G. rufomaculans*, var. *cyclaminis,* though, perhaps, like many of the fungi nominally connected with that of the bitter rot doubtfully belonging to it, and with this the conidial *Colletotrichum* form. One other spot disease rather indefinitely described has been reported by Professor Halsted under the name *Phoma cyclamenae.**

In the plant houses of the University of Illinois in the winter of 1913-1914, there appeared in rather small quantity, a wilting of the older outer leaves of cyclamens at the flowering time, which, without any marked discoloration of the leaf, is attended by a frosty mildew on the under surface near the soil. There was also observed by Dr. J. T. Barrett in the autumn of 1907, a considerable epidemic of a leaf spot on cyclamen, this disease being marked by deep brown discoloration of the large affected areas on the upper surface of which small pustules occurred with extruding tendrils of colorless spores.

The disease of 1913-14 is found to be due to a mycelium that appears to be localized within the wilting parts of the leaf and that fruits by sending out tufted colorless conidiophores on the lower surface, the stomata through which these tufts protrude on the diseased area being rather conspicuously brown or red in contrast with the general whitish green of the lower leaf surface. From the ends of the conidiophores simple chains of colorless conidia reaching a length of one hundred microns or more are cut off, these chains being slightly moniliform by the constriction between the spores which remain attached together for a long time but are easily and completely disassociated in the preparation of material for examination.

No doubt can exist that this fungus corresponds to the conidial stage of many ascomycetes the mature form of which is usually found on dead leaves later, and although it violates the fundamental division of the hyaline spored Mucedineae between two-celled and many-celled forms, it is hardly to be referred elsewhere than to the form-genus *Ramularia,* many other species of which fail to show more than a single septum in the conidia. Thus far, no hyphomycetous fungus has been

*The type material of this, as I learn from Professor Halsted, has been lost.

made known for the genus *Cyclamen*, though *Ramularia* occurs on related genera of the Primulaceae. The form referred to here may be characterized as follows:

Ramularia cyclaminicola n. sp.—Hypophyllous, not (as yet) forming spots. Fertile hyphae colorless, emerging in small tufts from the stomata on the lower surface of the wilting foliage, slender, each ending in a moniliform chain of five or ten little elongated conidia. Conidia colorless, somewhat pyriform or elliptical or oblong, acute at one or both ends, 4 or 5x10 to 15 or even 20 microns, scarcely granular, two-celled at maturity. On living leaves of *Cyclamen latifolium*, cultivated in Illinois, (*Trelease*, 1914).

The foliage of some of the plants this same season was disfigured by more or less irregular dark brown dried spots but with no evidence of a fungus as the cause of discoloration. On the other hand, the spots produced in 1907, as shown by material preserved by Dr. Barrett, were fruitful, having minute, colorless one-celled spores oozing from small brown pycnidia, so as to fall into one of the form-genera *Phoma* or *Phyllosticta*—the line between which is purely arbitrary and differently drawn by different writers, the most satisfactory division apparently being that which refers all of the leaf fungi of this type to *Phyllosticta* and reserves *Phoma* for those which occur on other parts of the plant. On this basis, therefore, the present fungus falls into the genus *Phyllosticta*, differing from any of the species so far described, however, in the large size of the leaf spots that it causes—the center of these spots only being occupied by fruit of the fungus.

While the characters used to separate the various forms of *Phyllosticta* and *Phoma* are not such as to give rise to a very confident belief that they are to prove constant when much material is observed, those that the present form presents differ from those ascribed to the species of *Phyllosticta* already described as occurring on cyclamen sufficiently to make it seem desirable to give the present form a distinctive name, with the following characters:

Phyllosticta cyclaminicola n. sp.—Epiphyllous on more or less zonally shaded dark brown spots at length five to thirty millimeters in diameter, the fruiting center paler and sometimes falling away. Pycnidia brown, minute, some 10 microns in diameter, irregularly and rather sparsely distributed over the center of the spot. Pycnospores extruding in short thick tendrils, colorless, oblong, rounded at both ends, one-celled, some 3-4x6-8 microns, highly refractive. On living leaves of *Cyclamen latifolium* cultivated in Illinois. (*Barrett*, 1907.)

Papers on Physics, Chemistry
and Engineering

DETERMINATION OF ATOMIC WEIGHTS OF THE RARE EARTH ELEMENTS

B. S. HOPKINS, UNIVERSITY OF LLLINOIS

Theoretically the determination of the atomic weight of an element is exceedingly simple. It consists in preparing a pure compound of the element and then transforming it completely into some other compound of the element. The change in weight which is produced by the change in composition gives sufficient data for the calculation of the atomic weight. In practice, however, the determination of the atomic weight of any number of the rare earth group becomes very difficult. This difficulty is apparent when we consider that the rare earth elements are found only in complicated mixtures and that the properties of these elements are so similar that the preparation of a pure compound is attended by well-nigh insurmountable difficulties. The methods used for the determination of the atomic weights of members of this group may be illustrated by the steps necessary for the preparation of pure yttrium material and the calculation of the atomic weight by the use of the ratio Y_2O_3 to $2YCl_3$.

In purifying yttrium material, the mineral, such as gadolinite, was ground finely and extracted with HCl or H_2SO_4. Silica was removed by dehydration. Then the rare earths present in solution were precipitated by hot oxalic acid. The material was then converted to the anhydrous sulfates which were dissolved in water and solid Na_2SO_4 added to precipitate the members of the cerium group. The members of the yttrium group, which are not precipitated by Na_2SO_4, may be separated from each other in two ways (1) by the difference in the solubility of some salts such as the bromates; (2) by slight differences in basicity which permits their gradual separation through the method of fractional precipitation. Utilizing the difference in solubilities the method of fractional crystallization was used by placing a quantity of the mixed bromates in a flask and adding sufficient water to take the whole into solution. Then part of the water was evaporated on the steam bath and the material left to crystallize. Obviously the least soluble crystallized first, leaving the more soluble portions in solution. This liquid was thoroughly drained away from the crystals into a second flask from which more of the water was evaporated and the process of crystallization repeated. By adding small quantities of water to the first flask and then pouring the soluble portion from each flask into the next in the series, the material was split into fractions of different solubilities. By continuing this method of fractional crystallization for a period of about two years distinct colors were seen in portions of the series, indicating a partial separation of the elements which were present in the original mixture.

Portions of such a series which showed similar properties were set out and the material further fractionated by adding a precipitant in small quantities. After each addition the precipitate was removed, and in this manner several fractions were obtained with varying degrees of basicity. The precipitants used in this work were K_2CrO_4, NH_4OH and $NaNO_2$. The effect of the treatment was followed by observing the changes in the lines of the absorption spectrum and by using trial methods for determining the atomic weights.

The best yttrium material obtained contains only traces of erbium and holmium. The final determination of the atomic weight is being made in the following manner: A quantity of pure yttrium oxide is placed in a double-necked quartz flask and its weight determined. This is then dissolved in pure HCl and the flask is attached to a drying train through which dry air is passed until the solution in the flask crystallizes. Then the temperature of the flask is gradually raised while dry nitrogen and dry HCl are successively passed through the flask until the chloride is thoroughly dehydrated. Finally the anhydrous chloride is fused in an atmosphere of HCl.

The results so far obtained indicate that the atomic weight of yttrium is somewhere between 88.5 and 89.

A NEW LAW RELATING IONIZATION PRESSURE AND CURRENT IN THE CORONA OF CONSTANT POTENTIALS

By Earle H. Warner, University of Illinois

The "corona" is the glow which surrounds conductors when there exist high potential differences between them and neighboring conductors.

Mr. Farwell has shown that at the instant the corona appears the pressure in the corona apparatus increases. It was the object of the experiments which have been performed to test the relationship between the ionization pressure and corona current.

The corona apparatus was of wire and co-axial cylinder type. The continuous potential was obtained from a battery of forty continuous current, shunt wound, 500-volt generators connected in series. The corona current was measured with a D'Arsonval galvanometer. The increase in pressure was measured by a Bristol aneroid pressure meter. Experiments have been performed with dry air, hydrogen, nitrogen and carbon dioxide in the corona tube. In every case, with the wire positive, the ionization pressure is exactly proportional to the corona current. With the beads, which accompany the wire negative, the pressure varies with the arrangement of the beads and since these are not stable it is impossible to accurately determine the desired relationship.

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THE SUPPOSED EFFECT OF THE SHAPE OF THE CONTAINER ON THE VOLUME OF A GAS

ABSTRACT

W. A. Noyes and L. C. Johnson, University of Illinois

From a discrepancy between his earlier values for the ratio of hydrogen to oxygen in water, Morley assumed that the shape of the vessel in which the gas was measured might actually affect the volume. In this investigation, both hydrogen and oxygen have been measured in tubes and in bulbs and the results show that any difference in volume which may exist is much too small to account for the disagreement as reported by Morley.

(Complete paper published in the Journal of the American Chemical Society, Vol. XXXVIII, No. 5, May, 1916.)

MAGNETIC PERMEABILITIES OF 50000

Trygve D. Yensen, University of Illinois

Ten or fifteen years ago we used to read about great improvements being made in iron for magnetic purposes, due chiefly to the excellent work done by Sir Robert Hadfield. He succeeded in raising the maximum permeability of Swedish charcoal iron, at that time regarded as the best magnetic iron obtainable, from 2000 to 5000 by alloying it with small percentages of silicon or aluminum. Furthermore, the area of the hysteresis loop, or the hysteresis loss, was proportionately reduced, at the same time as the electrical resistance was enormously increased by the addition of either one of these alloying elements. As Hadfield's alloys could be readily produced in commercial quantities it was not surprising that his discoveries resulted in the almost immediate adoption of silicon steel for transformers, in which efficiency and high permeability are of the utmost importance.

Since that time only minor improvements have been made, and whatever has been done has been due largely to modifications of Hadfield's alloys. Even in the laboratory maximum permeabilities above 10000 have been obtained only in very rare cases, and have been regarded as exceptional. It has been the privilege of the Engineering Experiment Station of the University of Illinois recently to produce iron and iron alloys with permeabilities all the way from 20000 to 50000 and with hysteresis losses of one-half to nearly one-tenth that of the best commercial silicon steel. It is unsafe at the present time to state exactly what the values are, as the methods of testing that have hitherto been regarded as standard have proved to be inadequate for this high permeability iron. The Burrows compensated double bar and yoke method gives too high a maximum permeability, too high retentivity and coercive force, too low hysteresis loss for low densities and too high for high densities. The ring method, while more satisfactory in this respect, is open to the objection that the flux distribution is not uniform, and besides is awkward to work with. The subject is at present being investigated both here at the University of Illinois and at the United States Bureau of Standards, and a more perfect method will undoubtedly be developed.

The method employed for the production of this high permeability material consists in melting electrolytically refined iron in a vacuum furnace, the absolute pressure being 0.5 mm. of mercury. The iron is allowed to cool in the furnace, and when removed has an appearance like that of nickel. The ingots thus produced are forged into rods and machined into proper test pieces. In this state, however, the magnetic properties are very poor, chiefly on account of the molecular strain caused by the mechanical treatment, and it is necessary to anneal the rods before the unusual properties are obtainable. This is done by heating the rods to 900° or 1100°C in vacuo followed by cooling at the rate of 30°C per hour down to room temperature.

Thus far we have investigated pure iron, iron-boron alloys, iron-carbon alloys, and iron-silicon alloys, besides the iron-cobalt alloy Fe_2Co. The iron-aluminum series is being investigated at the present time. It gives the average for a large number of samples of Vacuum Iron, the best of which is below what we can produce with certainty today. The curve just below that for the "Vacuum Iron" proper represents Swedish charcoal iron remelted in vacuo, showing the improvement obtained by the treatment. The curves for the commercial grades of iron are far below.

Turning now to the more recent results obtained with the silicon alloys. Here it is seen that two maxima occur in the curve for maximum permeability corresponding to two minima in the curves for hysteresis loss and coercive force. The first of these occurs with a silicon content of 0.15 per cent and the second with a silicon content of 3.5 per cent. The electrical resistance increases uniformly with the silicon content so that an alloy containing 3.5 per cent silicon has a specific resistance nearly five times that of pure iron.

Fig. 4 gives a comparison between the 3.5 per cent silicon vacuum-alloy and 4 per cent commercial silicon steel, both tested by the Burrows method. It is seen that the maximum permeability is as 20 to 1, the hysteresis loss for $B_{max}=10000$ as 8 to 1, and the hysteresis loss for $B_{max}=15000$ as 4 to 1 in favor of the vacuum product.

Could this vacuum alloy be substituted for the present commercial steel in transformers and used in a form to give the same properties as shown in Fig. 4 it would be possible to increase the flux density from $B_{max}=10000$ gausses to nearly 15000 without increasing the required magnetizing force and at the same time to decrease the hysteresis loss to less than one-third. Consequently the cross section of the iron core for a certain flux could be decreased to two-thirds and the length of the copper wire for the windings could be correspondingly reduced. Thus besides a lowering of the hysteresis loss there would result also a lowering of copper loss, and, with the eddy current loss only slightly increased, the sum total should be a transformer of about two-thirds the weight with an energy loss of about one-half that of a similar transformer with an ordinary silicon steel core.

It is well known, however, that the core of a transformer must be made up of iron in the form of very thin sheets in order to keep the eddy currents down to a proper value, otherwise the loss caused by these eddy currents would be excessive. Now, the properties of the vacuum alloy were obtained with the alloy in the form of a rod 1 cm. in diameter. Whether it is possible to duplicate them with the alloy rolled into sheets of from 0.015 to 0.025 inches in thickness is as yet doubtful. We are at present investigating this phase of the problem.

The mechanical properties of the silicon series offers points of particular interest. Here it is seen that the strength increases as the silicon content increases, until the maximum strength is reached with about 4.5 per cent silicon. From this point on, the elastic limit coincides with the ultimate strength and both decrease very rapidly. The curves for reduction of area and elongation show that the alloys below 2.5 per cent are unusually tough, much more so than corresponding alloys made by the ordinary methods.

Of great interest is the critical point that occurs with about 2.6 per cent silicon. This point was first observed by the fact that two ingots, containing 2.55 and 2.57 per cent silicon respectively, were not forgeable but fell into a mass of crystals that apparently had no adhesive strength. As critical points are usually associated with the formation of definite compounds, it is of interest to note that a compound of the formula $Fe_{19}Si$, if it exists, would contain 2.56 per cent silicon, and similarly that a compound of the formula $Fe_{19}Si_2$ would contain 4.99 per cent. It was stated above that a critical point in the present case occurs with a silicon content of 2.55 to 2.57 per cent.

Furthermore, it is seen that there is another sudden change at about 5 per cent silicon. Whether this agreement is a mere coincidence, or whether these compounds or others, actually exist, has not been definitely determined, as cooling curves for these particular alloys are not available.

In conclusion it should be said that, while it has been possible by the vacuum method to produce iron of unheard of magnetic quality this iron is not yet ready to be put into practical use. It is even doubtful whether it ever will be possible to realize these properties in commercial apparatus. However, this investigation has given a new indication of the possibilities obtainable in the realm of magnetism, and who dare say that this is the end? If it is possible to increase the maximum permeability in one step from 10000 to 50000, we might look forward to permeabilities of 100000 or even more.

NOTES ON THE PROPERTIES OF STEAM

G. A. Goodenough, University of Illinois

The various properties of saturated and superheated vapors, pressure, temperature, volume, heat content, specific heat, etc., are not independent, but connected by certain well-known thermodynamic relations. Consequently the values of these properties when collected in tabular form are consistent when derived from formulas that satisfy the necessary thermodynamic relations.

The two most important relations are the following:

$$\left(\frac{\delta c_p}{\delta_p}\right)_T = -AT\left(\frac{\delta^2 v}{\delta T^2}\right)_p$$

$$r = AT\,(v''-v')\left(\frac{dp}{dt}\right)_{sat}$$

The first is a statement that the rate of change of the specific heat of superheated vapor with the pressure, holding the temperature constant, is with its sign changed equal to the product of the temperature and the curvature of constant pressure curves on the vT-plane. The second relation applies to the saturation condition and gives a relation between latent heat r, change of volume v''-v' during vaporization, and the slope $\frac{dp}{dt}$ of the saturation curve.

In the case of water vapor, the series of experiments in the Munich laboratory give fairly reliable information regarding the volume and specific heat of superheated steam. The problem lies in the correlation of these experiments through relation (1). It is one of exceeding difficulty, but has been successfully solved in the University of Illinois investigations. The method of attack is as follows:

A characteristic equation $v=f\ (p,T)$ was chosen and the constants were determined so as to satisfy the volume measurements. From this equation the second member of (1) was obtained and c_p was then readily expressed as a function of T. By adjustment of the constants, the resulting values of c_p were made to satisfy the specific heat measurements. Finally, the other properties derived from these equations were made to satisfy the second relation and all other outstanding requirements.

The result of the work is a table of the properties of steam that possesses absolute thermodynamic consistency and at the same time extreme accuracy.

SOME STRUCTURAL PROPERTIES OF GYPSUM AND OF REINFORCED GYPSUM

W. A. SLATER, UNIVERSITY OF ILLINOIS

LIST OF FIGURES

Recent developments in building construction requiring a light, cheap fire-resisting building material have brought about investigation of the structural properties of gypsum.

Nearly twenty years ago a reinforced gypsum floor was approved by the City of New York after a fire test at Columbia University Testing Station.[1] Similarly, load tests were made on gypsum floor construction early in the history of floor tests.[2] These tests made a creditable showing, but for some reason attention was directed away from gypsum toward Portland cement concrete, and it is only recently that investigation of gypsum has been receiving the attention to which the importance of the subject entitles it.

Engineers' opinions of gypsum seem usually to be based on observations of the gypsum block used for partitions. This block is used only in places where strength is not required and consequently it is designed to secure lightness rather than strength. Of the wet mixture used for this block over 50 per cent by weight is water.

Fig. 1 shows that such a mixture gives a very light wall, approximately three-eighths the weight of Portland cement concrete. Fig. 1 also shows that even with the smallest

[1] Test of Metropolitan floor system, May 20, 1897. See International Association of Testing Materials, Paper XXVII, by Ira H. Woolson and Rudolph P. Miller.

[2] See Eng. News Vol. XXXIV, page 333, Nov. 14, 1895.

amount of water practicable (about 35 per cent) the weight of dry gypsum is only slightly more than half that of concrete.

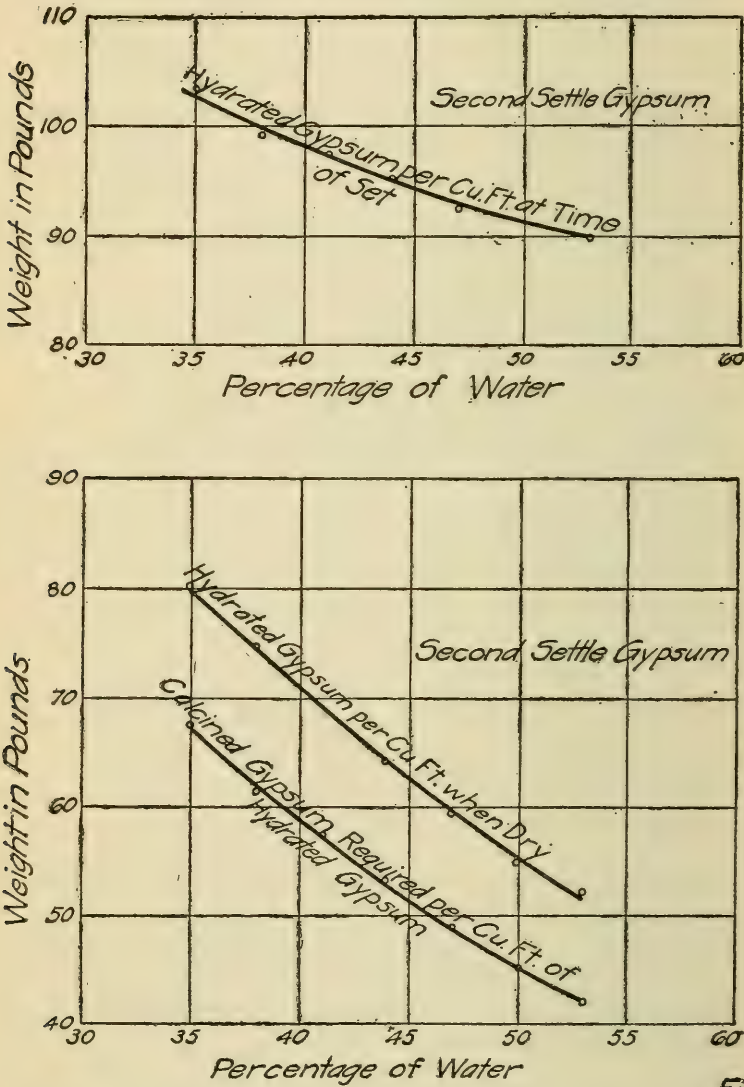


Fig. 1.

In all the tests referred to in this paper, except as otherwise noted, the amount of retarder used was 0.1 per cent, and the amount of water used was such as would give the same consistency to the mixtures for all specimens. This consistency, termed "standard consistency," required that the percentage of water used in gaging the mixtures be from 37 to 39 per cent by weight of the total weight of the water and gypsum used in the specimen.

All the compression specimens tested were cylinders having a height of twice the diameter. These were used because it has been found[3] that with specimens of this form slight variations in the dimensions of the specimen cause less variation in the strength than with specimens whose height is equal to the diameter. Also it is believed that the specimens used give strengths more nearly representative of what may be developed in a structural member than would a shorter specimen. A specimen whose height is equal to its

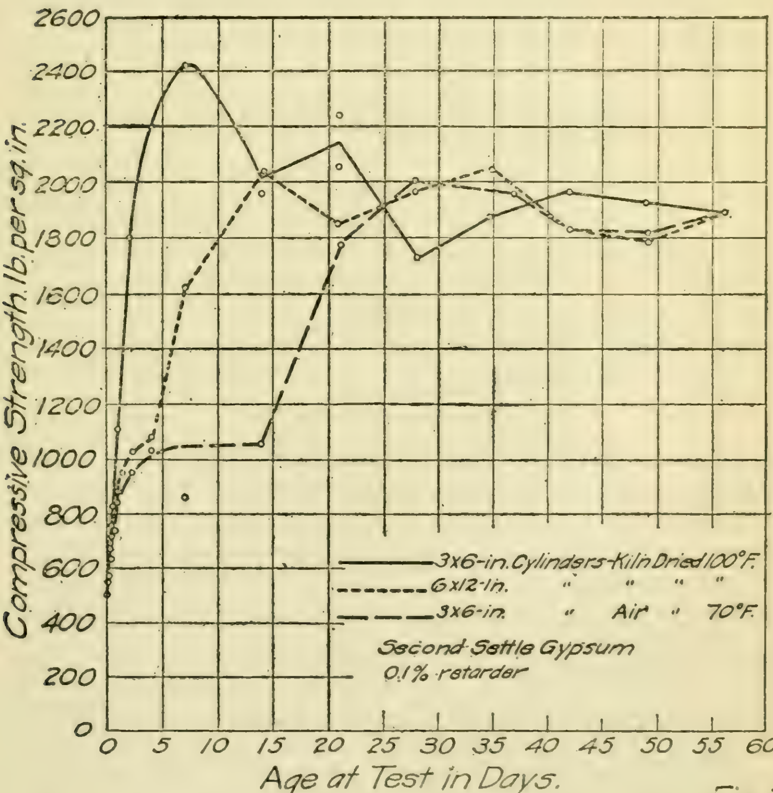


Fig. 2.

[3]See Journal of American Concrete Institute, Vol. 11, No. 6, October-November 1914, p. 424.

diameter probably would have a strength about 35 per cent greater than the strength of a specimen whose height is equal to twice its diameter.

Fig. 2 shows the increase in strength of gypsum with increased age after hydration. Each value given is the average strength of five 3x6-in. cylinders. Fig. 3 uses the same strengths as Fig. 2, but in Fig. 3 the strengths are plotted against the ratios of the weights of the specimens tested, to the weight of a thoroughly dry specimen. This indicates that the age affects the strength only as evaporation pro-

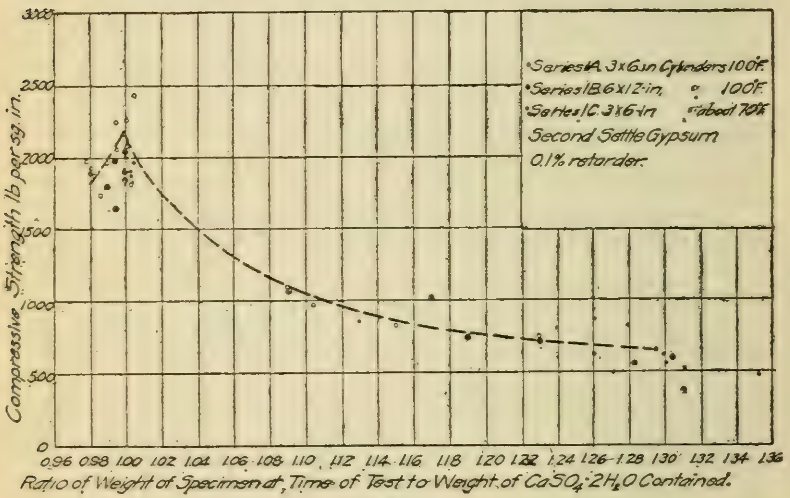


Fig. 3.

oughly dry, given the weight wet, the percentage of water used in gaging the mixture, and the percentage of water already in the calcined gypsum. The computations are based upon gresses with age. Within the accuracy of the weighings made to determine the rate of drying out, it has been possible to compute accurately the weight of the specimens when thorthe assumption that the process of hydration continues until all the gypsum becomes $CaSO_4 2H_2O$ and that all excess water is lost by evaporation. The assumptions may be incorrect, but the results show this to be a practical method of determining the final weight of the gypsum when the percentage of gaging water used and the percentage of water in the calcined gypsum are known.

Tests of specimens gaged with varying amounts of water (see Fig. 4) show that for cases in which strength is important a high strength can be reached by using a small amount of water. Results shown here are not for materials selected as the best, but for a good grade of second settle calcined gypsum and are shown in order to give an idea of the great increase in strength going along with a decrease in the percentage of water.

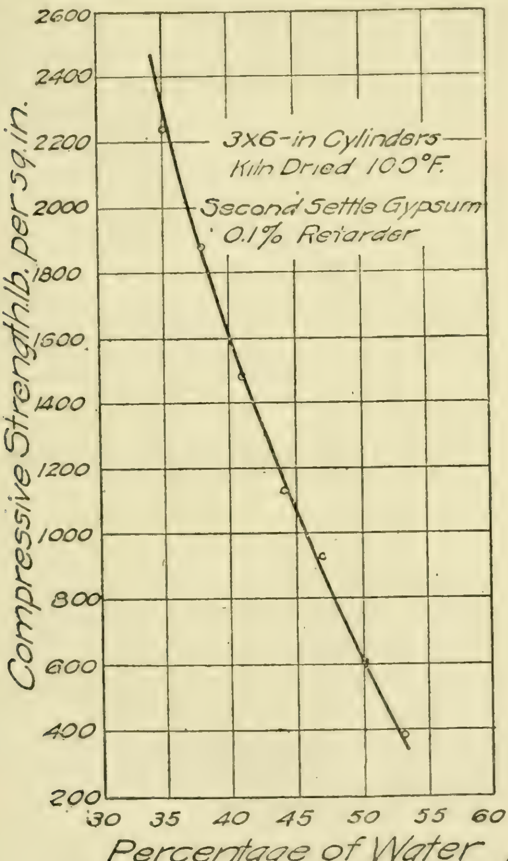


Fig. 4.

Tests made to determine the effect of water on the strength of specimens previously dried show that the absorption of a small amount of moisture by a thoroughly dry specimen reduced its strength materially. No further loss of strength seemed to be caused, however, by further exposure indefinitely to a very moist air. Immersing in water caused the strength to fall off rapidly to about 50 per cent of the strength of the dry specimen, but remaining in the water after this for an indefinite time (up to 176 days) caused little further loss in strength. Obviously this is more severe treatment than gypsum in actual service may be expected to receive. Fig. 5 shows the effect of standing in water for various lengths of time.

The time of set of gypsum may be controlled by the addition of a retardant. Fig. 6 shows the variation in strength due to the addition of varying amounts of retarder. In the study of this diagram it is of interest to note that for[4] first

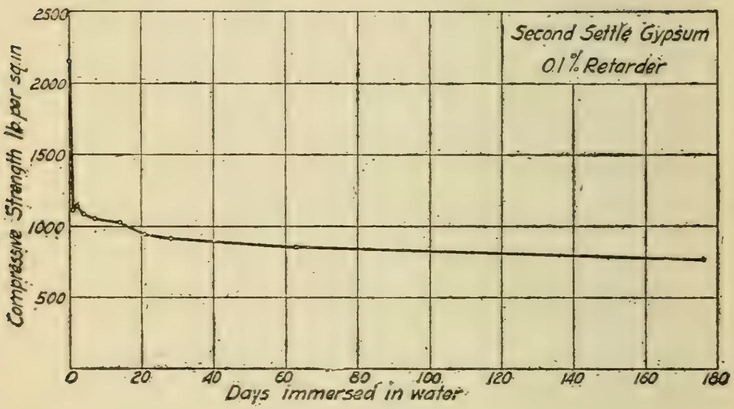


Fig 5

settle gypsum stored after hydration at about 70° F, 0.1 per cent retarder caused a material increase in strength, but that further addition of retarder caused a decrease in strength. The same effect was observed in a previous series of tests. At the same time it is important that with either first settle or second settle gypsum specimens dried at 100° F or less, as shown by this diagram, the addition of any amount of retarder caused a loss in strength.

All the strengths given heretofore were obtained from gypsum calcined at one of the mills of the United States Gypsum Company. Attention was given to carrying out the calcining

[4]When a charge of ground gypsum is subjected to a steadily increasing temperature, it goes through alternate stages of quiescence and of boiling due to the more rapid ejection of water as steam at certain stages than at others. Gypsum whose calcination stops with the end of the first boiling stage is termed here first settle gypsum and gypsum whose calcination stops with the end of the second boiling stage is termed second settle gypsum. See pp. 55 and 59, Bulletin No. 11, Oklahoma Geol. Survey, "Gypsum and Salt of Oklahoma," by L. C. Snider, and p. 107, Mines Branch Bulletin No. 84, "Gypsum Deposits of the Maritime Provinces," Mines Department, Ottawa, Canada.

process in such a way that at any future time a similar batch could be calcined and results of any of the tests checked or carried out more in detail. However, no attention was paid to selecting the strongest gypsum, and in order that a comparison might be possible betwen this and the company's regular practice, test specimens were made from samples of second settle gypsum taken from five mills of the United States Gypsum Company.

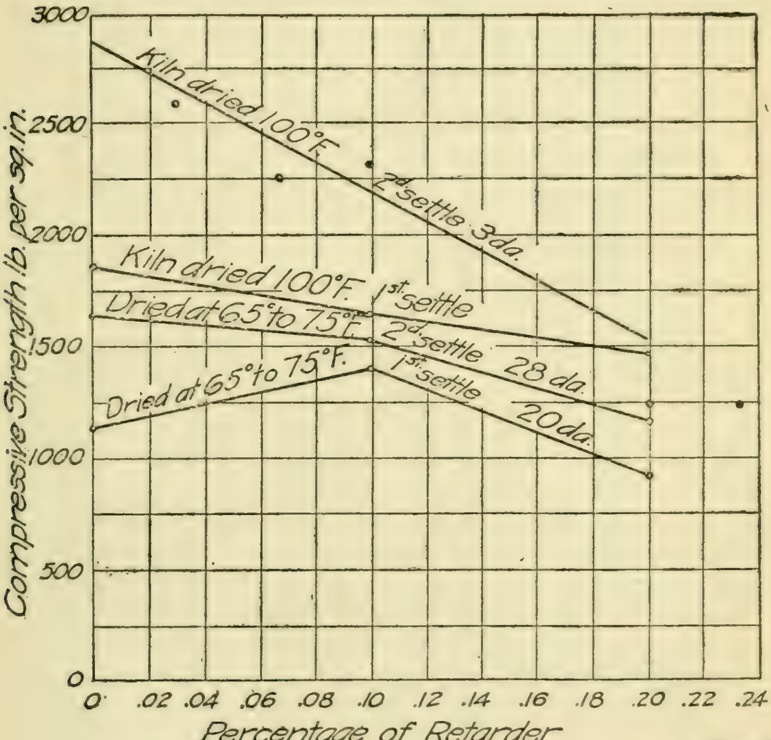


Fig. 6

The strengths of these specimens are given in Table 1, in which Gypsum No. 1 represents the specially calcined gypsum from which all the specimens previously discussed were made. These materials represent a geographical distribution covering five states and show a satisfactory uniformity in strength. In all these specimens 0.1 per cent retarder was used. The specimens were dried at 100° F and were tested at an age of four days.

TABLE 1.—STRENGTH OF SECOND SETTLE GYPSUM FROM VARIOUS MILLS

Gypsum No.	Compressive Strength lb. per sq. in.
1	2250
2	1590
3	1560
4	1720
5	1710
6	1860

Bond tests of specimens made by embedding ½-in. bars in 8-in. gypsum cylinders 8 in. long, showed a very satisfactory bond strength. A very great increase is shown with increased drying out. (See Fig. 7.) The smaller percentages of water also show great advantage over the wetter mixes.

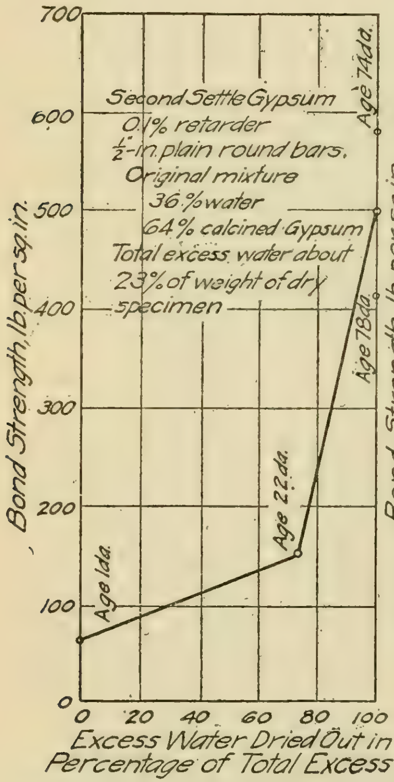


Fig. 7

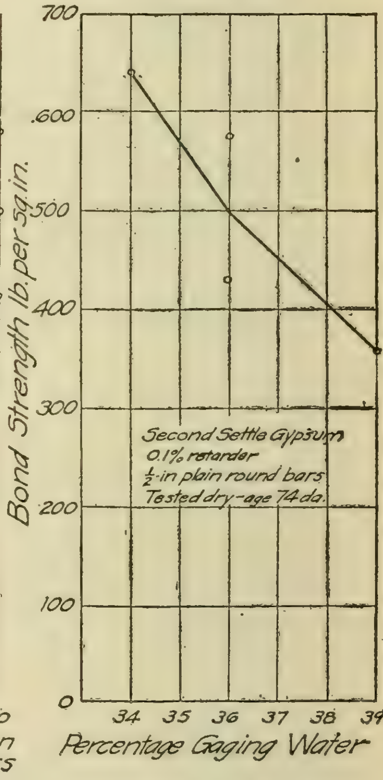


Fig. 8.

(See Fig. 8.) The driest mix shown, 34 per cent water, gave 640 pounds per square inch in bond strength. This mix may have been somewhat stiffer than could be handled in practical work, but that containing 36 per cent water was not too stiff for practical work and it gave a bond strength of 500 pounds per square inch.

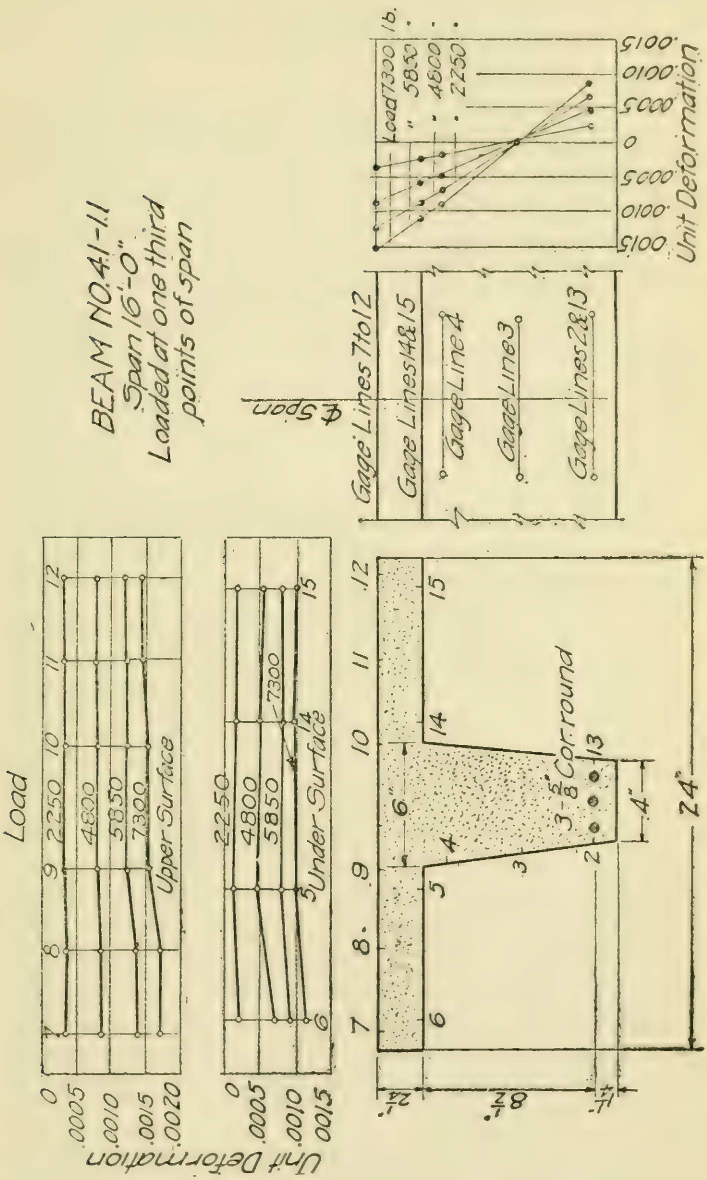

BEAM NO. 41-1.1
Span 16'-0"
Loaded at one third points of span
Load
Upper Surface
Under Surface
Unit Deformation
Gage Lines 7 to 12
Gage Lines 14 & 15
Gage Line 4
Gage Line 3
Gage Lines 2 & 13
℄ Span
Load 7300 lb.
5850
4800
2250
3-5/8 Cor. round
24"

Fig. 9.

Combination of lightness with considerable strength is a desirable property for a material to be used in floors for light loads on considerable spans. In such cases the weight of the building material may be the largest part of the load.

With this in mind, tests were made to determine the behavior of reinforced gypsum beams, both rectangular and T-shaped. At first the importance of giving gypsum specimens a chance to dry not being fully appreciated, the first and second series of beams were tested before they were entirely dry and without knowing just how much moisture they contained. The showing made by these beams was creditable, but in view of the marked increase in compressive strength and bond strength with increased drying (See Figs. 4 and 8), it is apparent that the results of the earlier beam tests may be misleading in some respects. They gave the impression that a means of developing the tensile stress by anchorage rather than bond would be essential, but the later development of a bond stress of 500 pounds per square inch, or possibly more, in thoroughly dry pull-out specimens, made from a mixture having the standard consistency, makes it appear that for positions not exposed to the weather or to wetting, anchorage may not be more necessary for a gypsum beam than for a reinforced concrete beam. However it must be recognized that there are few places where occasional wetting may not be possible. Mechanical would generally be an advantage for either reinforced gypsum or reinforced concrete.

The form of the T-beam tested is shown in Fig. 9. The main results of the tests are given in Table 2. Measurements of deformation in the reinforcement and in the gypsum were taken at the gage lines shown in Fig. 9. It is of interest that the compression in the flange was substantially uniform throughout the width of the flange of the T-beam, also that the deformations on a section at the center of the span were approximately proportional to their distance from the neutral axis. Diagrams showing these phenomena for one of the beams are shown in Fig. 9.

The tests here discussed point toward the suitability of gypsum for use in certain reinforced work and suggest possibilities which have not been entirely investigated. Certain difficulties also have been encountered, but for most of these, further investigation has already offered a satisfactory solution.

TABLE II.—DATA OF T-BEAM TESTS

Beam No.	Reinforcement: Description	Reinforcement: Area Sq. in	Age at Test Days	Load at First Crack pounds	Observed Steel Stress at First Crack lbs. per. sq. in.	Maximum Load pounds	Stresses at Maximum Load lb. per. sq. in.: Vertical Shear	Bond	Tension Calculated	Tension Observed	Manner of Failure
4.1-1.1	Three 5-8 in.	0.92	20	5250	19000a	7850	87	74	29200	28600	Stripping
4.1-1.2	cor. round straight	0.92	17	6300	22000	6300	70	60	24400	23000	of bars from stem
4.1-2.1	Two ⅜-in. cor. round and one ¼-	0.27	19	3200	31500b 38000c	3700	41	70	48000	d	Tension
4.1-2.2	in. cor. round, all bars straight	0.27	17	3150	25000b 29000c	3750	42	71	48000	d	in steel
4.1-3.1	Two 5-8 in. cor.	0.61	Accidentally broken before test								Stripping
4-1-3.2	round, looped at ends for anchorage	0.61	15	6650	24000	6650e 7550f	74 86	95	39500 44800	36000 41000	of bars from stem

NOTES

a. This crack did not extend higher than the level of the reinforcement before failure.

b. Under load point (one-third point of 16-ft. span.)

c. At center of span.

d. Had passed yield point.

Span of all beams 16 ft. Loads applied at one-third points of span.

e. Load indicated by dial

f. Corrected load.

WIND STRESSES IN STEEL SKELETON CONSTRUCTION

W. M. Wilson, University of Illinois

I. DEFINITION OF STEEL SKELETON CONSTRUCTION

By steel skeleton construction is meant that type of building construction in which the frame is made up of a system of steel columns and girders so planned that the loads from the walls and floors are delivered by the girders to the columns at each story. Each floor slab is supported on steel beams, and at each floor the walls are supported on steel beams framed into the columns, so that the floors and walls of one story, so far as support is concerned, are entirely independent of the floors and walls of all other stories. As seen in elevation, the steel work of such a building is made up of a series of rectangular frames. This is the type of construction that is used in practically all modern high buildings.

II. HOW A STEEL SKELETON FRAME RESISTS WIND PRESSURE

The wind pressure on a building acts upon the outside wall and is delivered by the wall to the steel frame. It is customary to assume that the wind load is applied to the steel frame at the level of the floors only. A bent of a building which is designed to resist the wind load is, therefore, considered as being acted upon by a series of concentrated horizontal forces at the various floors. The force at the top of the top story tends to make the top of the story more horizontally relative to the bottom of the story. For a twenty-story bent, the force at the top of the twentieth story and also the one at the top of the nineteenth story, tend to make the top of the nineteenth story move horizontally relative to the bottom of that story. In the same way, for any story, all of the forces above the story tend to make the top of the story in question move horizontally relative to the bottom of that story. The bottom of a story is prevented from moving horizontally because of its connection to the foundation by means of the intervening stories of the bent. For any story, therefore, the forces acting on the bent above the story in question tend to move the top of the story horizontally in one direction, whereas the stories below act horizontally upon the bottom of the story, in the opposite direction, to prevent it from moving horizontally in response to the forces above. That is, there is a shear in the story, and this shear is equal to the sum of the horizontal forces acting upon the bent above the story in question, including the force at the top of the story.

Fig. 1 represents the tenth story of a three-span bent. The force W applied at the eleventh floor is equal to the sum of all the horizontal forces above, including the one at the eleventh floor. W tends to push the top of the tenth story to the right. The force w is the wind load at the tenth floor. The

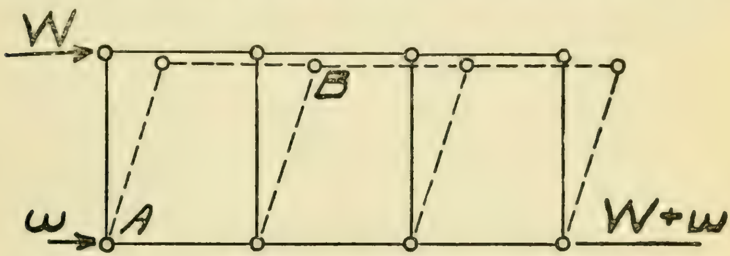


FIG. 1

force W+w is the resistence which the ninth story offers to prevent the bottom of the tenth story from moving to the right. If the columns and girders were hinged at the corners the frame would collapse as indicated by the dotted lines. The bracing added to prevent the frame from collapsing is called the wind bracing.

The easiest way to prevent the frame from collapsing would be to put in a diagonal tension member from A to B. This, however, it is not practicable to do inasmuch as diagonal bracing in the exterior walls would interfere with the windows, and all interior walls must be made so that they can be removed to meet the changing needs of the tenants. It is therefore necessary to make the frame capable of resisting shear without interfering with the clear rectangular space between the columns and girders.

If the connections between the columns and girders are made rigid, that is, if the columns can not turn relative to the girders, the frame, when subjected to a shear, instead of collapsing will take the form shown in Fig. 2. The columns of this latter frame tend to fall over to the right, the same as the columns of the frame in Fig. 1, but the girders at the tops of the columns hold the top ends in a nearly vertical position and likewise the girders at the bottom hold the bottom ends in a vertical position. That is, a column as a whole is not free to fall over, and the top can only move to the right by moving relative to the bottom when both the top and bottom remain in a nearly vertical position. Under these conditions a column is capable of resisting a horizontal shear.

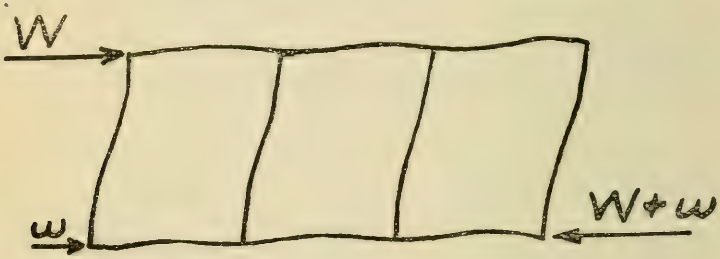


FIG. 2

The columns naturally take the position shown by the dotted lines in Fig. 1, that is, they tend to rotate and they are prevented from rotating only because the girders hold the ends in a nearly vertical position. In other words, and this is a fact that should be kept clearly in mind, the columns are the overturning members and the girders are the resisting members.

As stated above, the columns represented in Fig. 2 are subjected to shear. Since it is considered that no horizontal forces act upon the steel frame between the floors, the shear on a column is uniform for a story height. This shear produces a bending moment in the column, that is, the stress in the column due to the wind is tension on one side and compression on the other. From the form which the column takes when strained, it is apparent that for a particular side of any column if the stress at one end is compression that at the other end is tension, or the reverse. That is, the bending moment and also the bending stress changes sign, or passes through zero, some place between the two ends of the column.

The point where the moment changes sign is called the point of contra-flexure. The conditions at this point are the same, as far as stresses are concerned, as if the column were cut and the two parts were connected with a frictionless hinge. There is a shear but there is no moment at the point of contra-flexure.

Since a girder is subjected to forces resulting from the wind load only at points where the girder is connected to the columns, the shear on a girder is uniform between columns. The shear in the girder produces a bending moment and this bending moment changes sign in the girder the same as in a column.

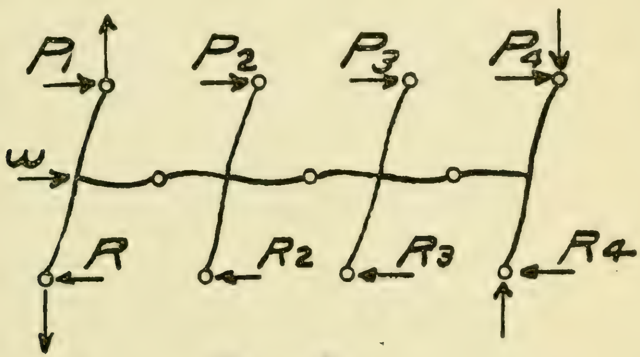


FIG. 3.

III. APPROXIMATE METHODS OF CALCULATING WIND STRESSES

In Fig. 2 the action of the portion of the bent above the tenth floor, upon the tenth floor is represented as a single force W; and the action of the tenth story upon the story below is likewise represented as a single force W+w. In reality the horizontal shear is transmitted from story to story through the columns.

If a column is divided at the point of contra-flexure, represented in Fig. 3 by a small circle, the upper portion of the column will exert upon the lower portion a horizontal shear, but no moment. (There is also a vertical force, but it is neglected in this discussion.) The total shear above the tenth floor is represented by W. It is equal to the sum of the shears, P_1, P_2, P_3 and P_4, in the columns. The shear is constant between the tenth and eleventh floors, whereas the moment varies and passes through zero at the point of contraflexure.

If the columns in the story just below the tenth floor are divided at the point of contra-flexure the lower portion of each column will exert upon the upper portion a shear, but no moment. These shears are represented by R_1, R_2, R_3 and R_4. Likewise if each girder is divided at its point of contraflexure each part would exert upon the other part a shear, but no moment.

If the dimensions of a building are known and a wind pressure, for the purpose of design, is assumed, the total shear upon each story of the building can be determined. If therefore the distribution among the columns of the total shear upon a story is known, and the location of the point of contraflexure of all members is known, the bending moment in the columns and girders can be determined. Unfortunately, however, the exact mathematical determination of the above quantities is very long and complicated.

While some effort has been made to devise an exact analysis of the wind stresses in the steel frames of office buildings,[1] designers of buildings for the most part, have been content to use approximate methods.

Four approximate methods have been used. For convenience in reference these will be designated as Method I, Method II, Method II and Method IV, respectively. Mr. R. Fleming presented the first three methods in Engineering News.[2] These methods, as applied to a building in which all columns of a story have the same section, are based upon the following assumptions:

ASSUMPTIONS IN METHOD I

1. A bent of a frame acts as a cantilever.

2. The point of contra-flexure of each column is at midheight of the story.

[1]Wind Stresses in the Frames of Office Buildings, by Albert Smith, Journal Western Society of Engineers, Vol. XX, No. 4, p. 341.
Stresses in Tall Buildings, by Cyrus A. Melick, Bulletin No. 8, College of Engineering, University of Ohio.
The Theory of Frameworks with Rectangular Panels and Its Application to Buildings which have to Resist Wind, by Ernst F. Jonson, Tran. Am. Soc. C. E., Vol. 55, p. 413.

[2]Wind Bracing Without Diagonals for Steel-Frame Office Buildings, Engineering News, March 13, 1913.

3. The point of contra-flexure of each girder is at its mid-length.

4. The direct stress in a column is directly proportional to the distance from the column to the neutral axis of the bent.

ASSUMPTIONS IN METHOD II

1. A bent of a frame acts as a series of portals.

2. The point of contra-flexure of each column is at mid-height of the story.

3. The shear is the same on all columns of a story.

4. Each pair of adjacent columns of a bent acts as a portal, and each interior column is a member of two adjacent portals. The direct stress in an interior column, when the column is considered as a member of the portal on one side, is of opposite sign from the direct stress in the same column when considered as a member of the portal on the opposite side and the resultant direct stress is equal to zero.

ASSUMPTIONS IN METHOD III

1. A bent of frame acts as a continuous portal.

2. The point of contra-flexure of each column is at mid-height of the story.

3. The direct stress in a column is directly proportional to the distance from the column to the neutral axis of a bent.

4. The shear is the same on all columns of a story.

Professor Albert Smith, in a paper before the Western Society of Engineers, describes a method which he has used in his classes in Structural Engineering at Purdue University. This method is here designated as Method IV:

ASSUMPTIONS IN METHOD IV

1. The point of contra-flexure of each column is at mid-height of the story.

2. The point of contra-flexure of each girder is at its mid-length.

3. The shears on the internal columns are equal and the shear on each external column is equal to one-half of the shear on an interior column.

If all of the assumptions of any one of these methods are accepted, the stresses in a frame may be determined by applying the fundamental equations of static equilibrium.

4. *Slope-Deflection Method.* — The four approximate methods described above are all short and simple and, when any one of them is considered by itself, the assumptions upon which it is based seem reasonable. It is an unfortunate fact, however, that if the four methods are applied to the same frame, the results obtained by the four methods are radically different. Furthermore in the absence of an accurate method to be used as a standard of comparison, it was impossible to judge of the relative accuracy of the approximate methods.

The writer, assisted by Mr. G. A. Maney, devised a method known as the slope-deflection method to be used to determine the relative accuracy of the approximate method.[8]

It can be proven that the moment at the end of a member in flexure is given by the equation

$M_{AB}=2\ E\frac{L}{I}(2\ \Theta_A+\Theta_B-3\frac{d}{L})$, in which

M_{AB}=the amount at A in the member A B.

Θ_A=rotation of the tangent to the elastic curve of member. at A due to the stress, or the change in the slope of the member at the end A.

Θ_B=rotation of the tangent to the elastic curve of the member at B due to the stress, or the change in slope of the member at the end B.

d=deflection of one end of the member relative to the other end, measured in a direction normal to the original position of the member.

L=length of the member.

1=moment of inertia of the section of the member.

E=modulus of elasticity of the material.

[8]Bulletin No. 80, Engineering Experiment Station, University of Illinois.

That is, the moment at the end of a member can be expressed in terms of the changes in the slopes at the ends of the member and in terms of the deflection of one end of the member relative to the other end.

Neglecting the change in length of a member due to axial stress, the deflections of all columns in a story of a bent are equal, and the deflection of the girders are equal to zero. If the connections between the columns and girders are perfectly rigid all members intersecting in a point are subjected to the same angular strain at that point. The unknown quantities for each story of a bent are therefore one change in slope, or Θ, for each intersection of a column with a girder, and one deflection for the story as a whole. That is, there are as many unknowns per story as there are columns plus one.

If the point in which a girder intersects a column is considered by itself since it is in equilibrium the algebraic sum of the moments acting upon the points equal zero. A moment equation therefore can be written for each intersection of a column with a girder, or as many equations can be written for each story as there are columns in the bent.

If all of the columns in a story of a bent are considered together, the algebraic sum of the moments at the tops and bottoms of all of the columns equals the total sheer in the story multiplied by the story height.

All of the above moments are moments at the ends of the girders and columns. As explained above these moments can be expressed in terms of the changes in slopes, at the ends of the members and the deflections of one end of a member relative to the other end. The total number of equations in one story of a bent is therefore equal to the number of columns in the bent plus one. The number of unknowns in the equations for one story of a bent is equal to the number of equations for the story, but the equations for one story contain unknowns from the story above and from the story below the one in question. It is therefore impossible to isolate the equations for one story and determine the unknowns. There is no story to contain unknowns above the top story, and the bottoms of the columns of the bottom story are usually assumed to be fixed. Under these conditions there are as many equations for a bent as a whole as there are unknowns and the unknowns can be determined.

V. CONCLUSIONS

The number of equations involved in the slope-deflection method is so great that the method can not be used in designing buildings. The method, however, was used by the writer and Mr. Maney to determine the stresses in a number of typical bents, after which the stresses were also determined in the same bents by the four approximate methods described above. As a result of these calculations it was found that for bents for which all columns of a story have the same section Method I and Method IV are accurate enough for the purpose of design.

HEAT TRANSMISSION OF SIMPLE AND COMPOUND WALLS, WITH SPECIAL REFERENCE TO BUILDING CONSTRUCTION

ABSTRACT

Arthur C. Willard, University of Illinois

1. Consideration of the theory involved in the transmission of heat through a wall, and the relation between radiation, convection and conduction as involved in the process.

2. The effect of air movement on the film of air in contact with the surface of the wall, and the difference between the air and surface temperatures.

3. Determination of coefficients of transmission, based on inside and outside air temperatures.

1. The transmission of heat through a simple or compound wall, such as may be used in practice for the exterior walls of buildings, is a phenomenon of very general and practical interest. The calculation of the amount of heat transmitted in this way becomes one of the determining factors in proportioning any sort of heating or refrigerating system, and also serves as a ready means of comparing the relative heat insulating efficiencies of any form of standard wall construction.

2. The theoretical data on radiation, convection and conduction available in this field has not been found readily applicable to conditions as they actually exist in practice, as the following considerations will show. In the first place we are

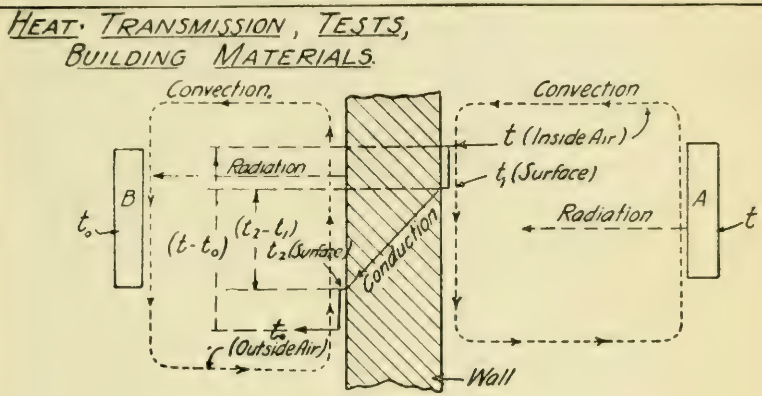


FIG. 1

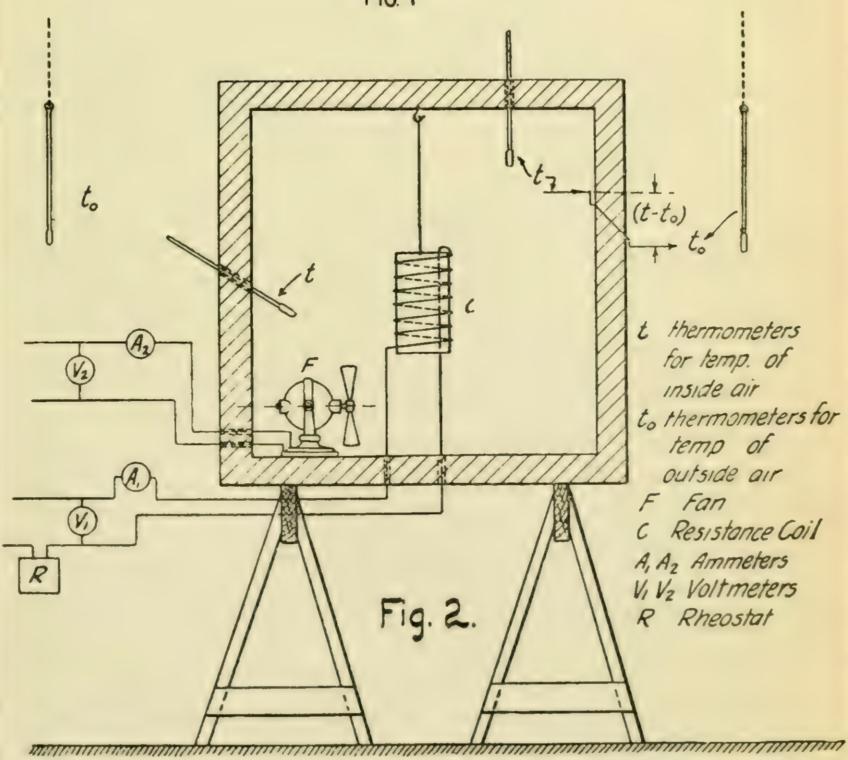


Fig. 2.

forced to base our calculation on the *air temperatures* on the two sides of the wall since in any problem of this sort we are only concerned with maintaining some fixed or desired internal "room" temperature when a given "outside" temperature exists.

3. A reference to Figure 1 will show that these two *air temperatures* t and t_0 respectively, are not the same as the corresponding surface temperatures, indicated by t_1 (inside) and t_2 (outside), due to the fact that the surface film of air protects or jackets the surfaces in such a way that there is always a drop in temperature right at the surface as shown by the temperature gradient line. Moreover, this drop in temperature t-t_1, or t_2-t_0 varies with the character of the wall material and the rate of air movement over the surface. It is, of course, possible to calculate the heat transmission through the wall from the conductivity of the wall material alone provided the surface temperatures are given. The heat H transmitted by conduction would be, in B. t. u. per sq. ft. per hour, $_{x}\ (t_1 1 t_2)$. where C= the conductivity in B. t. u. per sq. ft. per unit thickness, and x= thickness in the same units; but the two terms of the binomial are unknown. In other words we must employ a unit of transmission based on air temperatures rather than surface temperatures.

4. If we now consider the phenomena taking place at either surface of the wall, we find that heat is being transferred (in the case of the inner surface) from the air and objects within the room, which are considered to be at the same temperature as the air; (1) by *radiation* from these objects; (2) by *convection* currents moving over the face of the wall and thereby losing heat by contact, as shown in Figure 1. Unfortunately, the determination of separate coefficients for radiation and convection for various wall surfaces is a most difficult problem; whereas the experimental determination of a single combined coefficient is a fairly simple matter. Moreover, the use of such a composite coefficient materially simplifies the calculation of suitable units of transmission based on air temperatures alone.

5. Assuming this combined surface coefficient K is known, we can find another expression for the heat H transmitted per sq. ft. of wall surface, which is K_1 (t-t_1) for the inside, and

K_2 (t_2-t_0) for the outside surface, since all the heat entering the wall by *radiation* and *convection* per sq. ft. of inside surface must pass through it by *conduction* and then be discharged from the outside surface by *radiation* and *convection.* It is assumed, of course, that the wall has come to a condition of equilibrium, and is transmitting heat uniformly. Moreover, the amount of heat transmitted by the wall per sq. ft. is also equal to U (t-t_0) where U is the unit of transmission to be determined, already referred to, based on air temperatures.

6. We now have four expressions for H, each of which represents the heat transmission per sq. ft., and involving U, C. K_1, K_2, and the four temperatures, in which only U, t_1, and t_2 are unknown. By elimination of t_1 and t_2 we find

$$U = \frac{1}{\frac{1}{K_1} + \frac{1}{K_2} + \frac{X}{C}}$$

for a simple wall, and for a compound wall in an exactly similar manner we obtain

$$U = \frac{1}{\frac{1}{K_1} + \frac{1}{K_2} + \frac{X_1}{C_1} + \frac{X_2}{C_2} + \frac{X_3}{C_3}} + \text{etc.}$$

where K_1 and K_2 are the respective inside and outside combined surface coefficients, and X is the thickness in inches of each material and C the corresponding conductivity.

7. The values of K_1 and K_2 for a given wall material are found to vary with the rate of air movement over the wall, and the results of tests show that K_1 (inside or still-air coefficient) is practically constant so long as the air movement is due to convection only. The value of K_2 increases with the wind velocity, and for brick ranges from 2.38 K_1 at 5 miles per hour to 4.22 K_1 at 20 miles per hour, with an average value of 3 K_1 at 13 miles per hour, which represents our mean winter wind velocity. It is therefore apparent that once this ratio is determined for any building material, it is only necessary to find values of C and K_1 in order to compute U for any wall.

8. The experimental determination of the values of U can, of course, be made on a limited number of wall constructions, and at the same time values of C and K_1 can be obtained. A thermal testing box as shown in Figure 2 is constructed of the material to be investigated, and a heating element of high resistance wire is centrally located within same. A small desk fan is used to maintain a uniform temperature all over the in-

EXAMPLES IN THE CALCULATION OF HEAT TRANSMISSION OF VARIOUS CONSTRUCTIONS

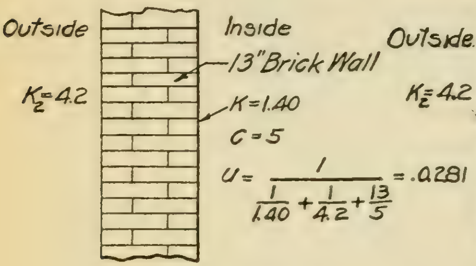


Fig. 3

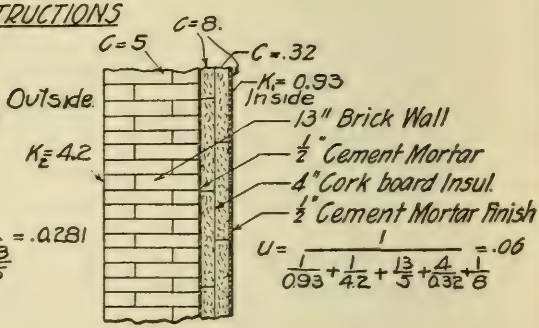


Fig. 4

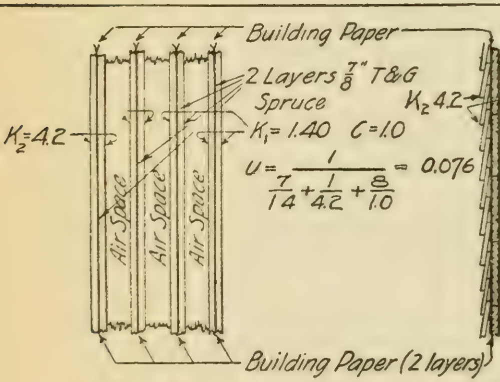


Fig. 5

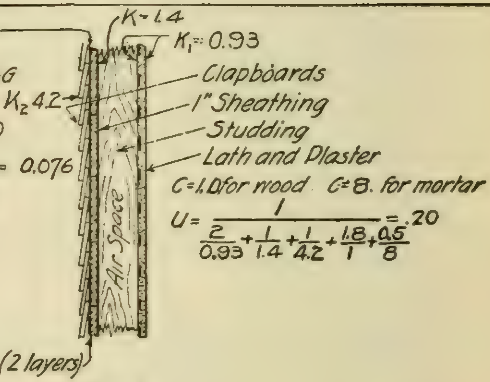


Fig. 6

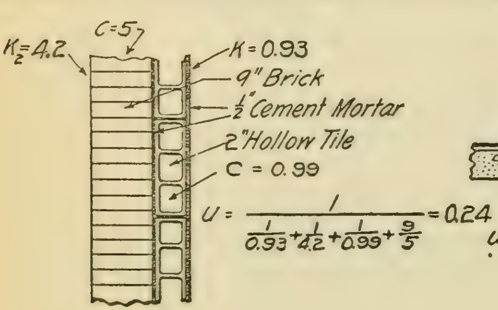


Fig. 7

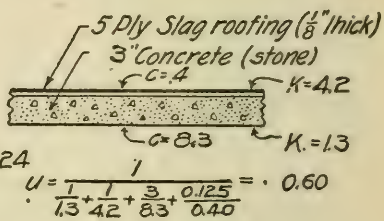


Fig. 8

terior of the box by suitable circulation of the air in the box. Direct current is supplied both coil and fan, and the total input in watts is determined from the ammeter and voltmeter readings. After the box has been under heat for at least 24 hours, and a condition of equilibrium has been established, it is only necessary to make one set of readings and by substitution in the equation US $(t-t_0)=3.415$ (W_1+W_2) find the value of U. The right hand member is, of course, the heat equivalent of the watts supplied, where W_1 and W_2=watts per hour supplied to fan and coil respectively. S=mean area of the six sides of the box.

9. Values of C and K_1 are determined at the same time by the use of thermo-couples, imbedded just in the surface of the wall materials, and used for measuring the surface temperatures t_1 and t_2. Thus, for the determination of conductivity, we have

$$(t_1-t_2)=3.415\ (W_1+W_2)$$

where the value of C is to be found per inch of thickness, and X+thickness inches. In a similar manner we may find values of K (still air) by using the outside surface temperature of the box, which is standing in still air, or

$$K_1S(t_2-t_0)=3.415\ (W_1+W_2).$$

10. Since it is manifestly impossible to test all forms of wall construction, it will, in general, be necessary to determine the value of U (the coefficient based on inside and outside air temperatures) by calculation. The equations already derived provide the means of doing this if values for the conductivity C and surface coefficients K_1 and K_2 are known. Tests now in progress in the Mechanical Engineering Laboratory of the University of Illinois, have, as one of their objects, determination of such data, and the figures numbered from 3 to 8 show application of this data to typical simple and compound wall constructions in solving for proper values of U for use in practice. Heat transmission tests on actual walls, such as here shown, give results, which agree very closely with the calculated values.

11. In practical application it is only necessary to multiply the coefficient U by the temperature range and then by the net area of the wall through which the heat loss takes place. Thus, for 70° inside air, and 0° outside air temperature, the total transmission loss for 1000 square feet of wall, such as shown in Fig. 3 is 0.291x(70—0)x1000=20370 B. t. U. per hour.

FATIGUE OF METALS UNDER REPEATED STRESS

H. F. Moore, University of Illinois

The failure of metal under repeated stress is a familiar phenomenon. Illustrations of such failure are furnished by the bending of a wire back and forth until it breaks; by the failure which takes place in railroad rails after a large number of trains have passed over them; and by the failure of boiler plates between riveted holes after the boiler has heated and cooled many times. The failure of metal under repeated stress is called failure by "fatigue." The old theory of such failures was that under repeated stress metal "crystalized" and became brittle, finally snapping between crystals. This belief lead many engineers to consider wrought iron to be superior to steel under repeated stresses, because wrought iron seemed fibrous in its structure while steel was crystaline.

The use of the microscope in studying metals has very generally discredited the "crystallization" theory. Under the microscope, the structure of all metals is seen to be crystaline, and no marked change in size of crystals can be detected in metal which has failed under repeated stress. The appearance of the fracture of metal to the naked eye is not a reliable indication of the structure of these metals. After a piece of soft steel is broken by a gradually applied tension the fracture will appear silky, not crystalline. If a piece of the same soft steel is nicked and bent it will break in two at the nick and the fracture will appear crystalline. If a piece of the same soft steel bar is bent back and forth a great many times it will finally snap in two with very little warning and the fracture will appear crystalline. The appearance of the fracture is dependent not only on the nature of the metal but upon the shape of the piece broken and the manner of applying load.

Examination under the microscope gives some idea of what happens when metal fails by fatigue. Figure 1*a* shows the appearance under the microscope of an unstressed piece of Norway iron. It is made up of crystals of pure iron and fibres of slag. Figure 1*b* shows the appearance of the same piece of iron after it has been subjected to several hundred repetitions of stress. Right across crystals appear fine lines; these are known as "slip lines" and indicate the splitting up of the crystal. Figure 1*c* shows the appearance of the same piece of iron after several hundred more repetitions of stress. The slip lines are more numerous than in Figure 1*b* and more crystals are "infected" by slip lines. Figure 1*d* shows the appearance of the same piece of metal just before it broke under repeated stress. The slip lines had become very numerous and at *aa* had spread until a crack had formed between the crystals. Shortly after the formation of this crack the piece failed.

The effect of this progressive failure of metal is to weaken the section of a bar, just as a nick cut into it would do, and explains why under repeated stress failure takes place suddenly just as it does when a nicked bar of metal is bent.

The problem which faces the engineer is to design members so that they will not fail under repeated stress. In general the smaller the stresses the less the danger of failure by repeated stress. A common idea concerning metals is that there exists an absolute elastic limit below which metal is absolutely elastic and below which no amount of repeated stress can injure material. It can not be stated positively whether such an absolute elastic amount exists, but in tests under repeated stress failure has occurred at stresses less than the elastic limit has commonly determined by refined testing methods.[1]

The best method of determining safe stresses for metals under repeated stress seems, to the writer, to be the direct experimental study of test specimens subjected to known stresses of varying magnitude repeated many times until failure occurs. Fig. 2 is plotted from the results of such a series of tests, and its general form is typical. Two methods of interpreting the results of such a curve are in use; in one it is assumed that the curve becomes horizontal, and from the test data a horizontal asmyptote to the curve is drawn by estimation, and the stress-ordinate of this asymptote taken as the endurance or "fatigue" limit for the metal. In the other method the assumption of a horizontal asymptote is discarded, and an attempt made to find some simple form of equation which fits the test data. For a wide range of test results of fatigue

[1]The method of determining the elastic limit of a material is to apply known loads to a specimen of the material and then to release the loads. Measurements of length of specimen are made before and after the application and release of each load. When any change in length can be detected after release of load, the elastic limit has been reached.

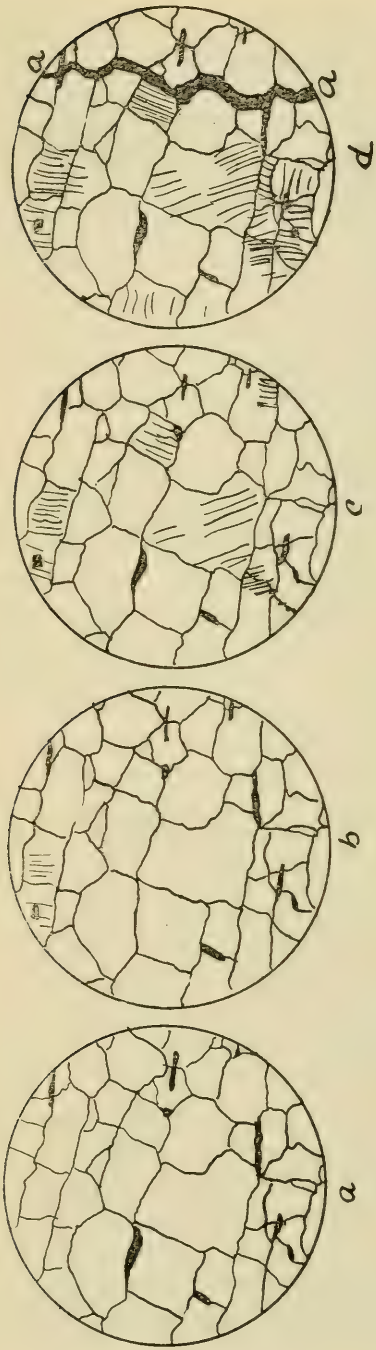


FIG. 1

From photomicrographs made in the Materials Testing Laboratory of the University of Illinois by H. R. Thomas tests the general form of equation,

$$S=AN^{-m} \quad \ldots\ldots\ldots\ldots(1)$$

seems to fit test results fairly well,[2] giving stresses for large numbers of repetitions which are somewhat lower than test results, and hence being on the safe side. In the above equation S is the fiber stress in pounds per square inch, N, the number of repetitions of stress necessary to cause failure, and A and m experimentally determined constants.

If the repeated stress on a metal is completely reversed there is much more danger of fatigue failure than if the stress varies from zero to a maximum in one direction. An examination by Mr. F. B. Seely and the writer, of the available published data on repeated stress tests, led to the proposed modification of equation (1) by the separation of the factor A into two parts: one denoted by B, an experimentally determined constant for a material, and the other denoted by $\frac{1}{1-Q}$, dependent on the range of stress to which the material is subjected, Q being the ratio of the minimum stress to the maximum. For completely reversed stresses Q is equal to —1, for stress varying from zero to a maximum, Q is equal to zero.

From the examination of available test data, including data for tests by various experimenters, tests with various kinds of testing machines, and tests of various sizes and shapes of test piece Mr. F. B. Seely and the writer have proposed for metals under repeated stress the general formula[3]

$$S=\frac{B}{(1-Q)\sqrt[8]{N}} \ldots\ldots(2)$$

For very high values of N this formula seems to give stresses somewhat lower than shown by test results; however, the test data for high values of N are so meager that, as the formula is on the safe side, no modification is recommended for general use.

A more convenient form of equation (2) for general use is

$$\log S=\log B-\log(1-Q)-0.125 \log N \ldots\ldots\ldots\ldots(3)$$

The accompanying table gives values of the constant B determined from a study of test data. In using the table, equation (2), or equation (3) a word of caution is necessary. In no case should the stress be taken higher than the safe stress

[2] So far as the writer is aware this form of equation for repeated stresses was first proposed by Professor Basguin of Northwestern University in 1910.

[3] See proceedings of American Society for Testing Materials for 1915 and for 1916, Moore and Seely on Repeated Stress. Also "Text-book of Materials of Engineering," by H. P. Moore, p. 169.

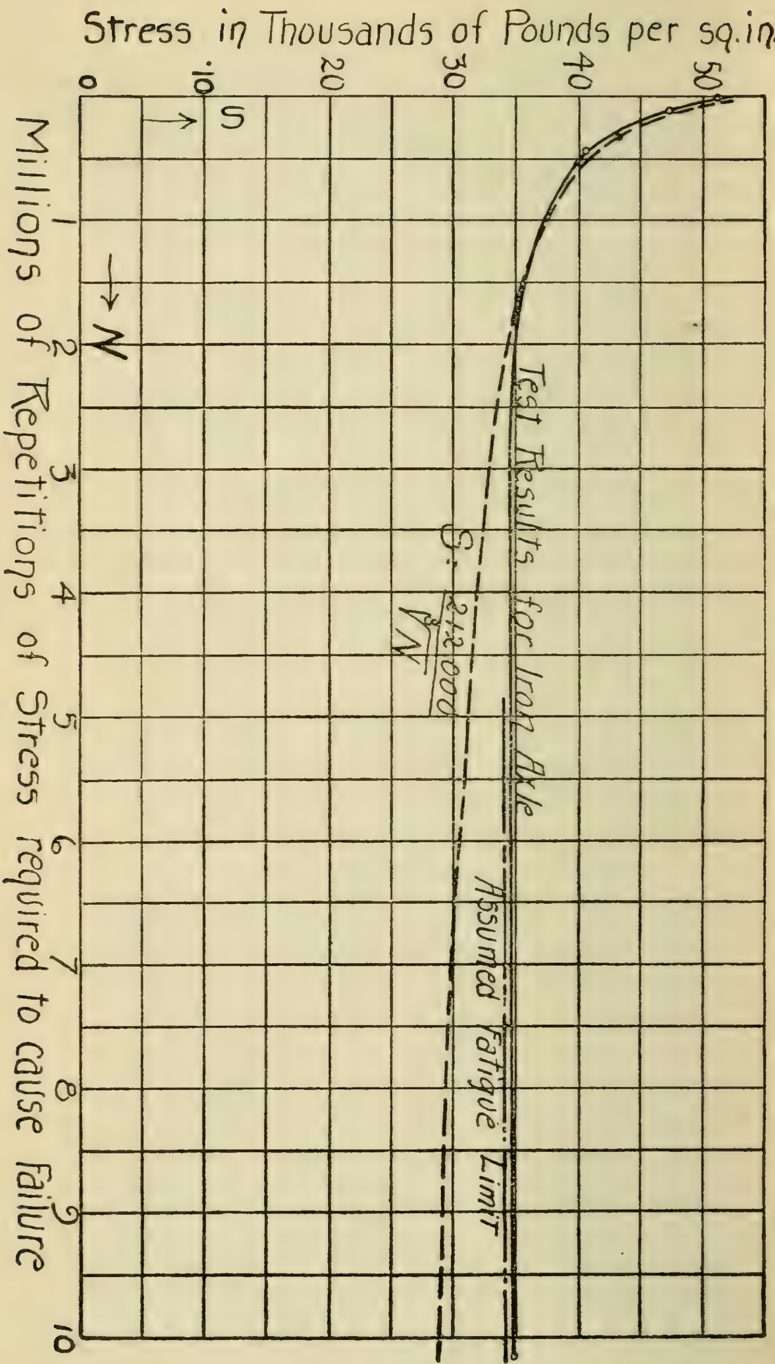

Stress in Thousands of Pounds per sq. in.
0
10
20
30
40
50
S
N
Millions of Repetitions of Stress required to cause Failure
1
2
3
4
5
6
7
8
9
10
Test Results for Iron Axle
S = 242000 / ∛N
Assumed Fatigue Limit

FIG. 2

under static load as given by engineers' hand books or as determined from test results. If the use of equation (2) or equation (3) with a proper factor of safety gives higher results than the safe static stress, it means that static stress conditions are the determining conditions, and that there is more danger of failure by static stress than by fatigue.

TABLE OF VALUES OF THE CONSTANT B.

Material	B
Structural Steel and Soft Machinery Steel	250,000
Wrought Iron	250,000
Steel, 0.45 per cent Carbon	350,000
Cold-rolled steel Shafting	400,000
Tempered Spring Steel	400,000 to 800,000

THE DETERMINATION OF V AND E/M FOR CATHODE RAYS AS A LABORATORY EXPERIMENT IN PHYSICS

CHAS. T. KNIPP, UNIVERSITY OF ILLINOIS

The writer has endeavored during the past two years to devise a method and apparatus[1] for the determination of v and e/m for cathode rays with sufficient accuracy to make it a desirable experiment for undergraduates in electrical measurements.

The parallel field method of J. J. Thomson has been simplified by using slow velocity cathode rays, such as are obtained from a Wehnelt or hot lime cathode.[2] These slow moving rays make it possible to use the earth's field for the magnetic deflection in place of the ordinary electro-magnet. This simplifies the formula and does away with the end corrections due to the spreading field at the edge of the magnet. The electrostatic deflection of the rays is obtained by the usual method of placing two parallel plates within the discharge tube.

With a beam 30 cm. long the magnetic deflections are of the order of one centimeter. This may be increased or diminished by using a *low* or a *high* potential in operating the Weh-

[1]Knipp, School Science and Mathematics, Vol. 14, 1914.
[2]Knipp and Welo, Terrestrial Magnetism and Atmospheric Electricity, June, 1915.

nelt cathode. The following table exhibits data obtained on succeeding days and over a wide range of conditions. The tube was operated by the instructor before the section. There were four sections.

Section	Discharge Potential	Pd. in Volts	y= Electric Deflection	z= Magnetic Deflection	v in cm /sec	e /m
K	1000 volts	27.0	1.3 cm.	0.65 cm.	8.9x10^9	2.16x10^7
L	800 volts	13.5	1.5 cm.	0.82 cm.	1.5x10^9	1. 4r10^7
M	800 volts	13.5	1.5 cm.	1.00 cm.	1.9x10^9	2. 1x10^7
N	1000 volts	13.5	0.97 cm.	0.82 cm.	2.4x10^9	2. 2x10^7

THE REFLECTING POWER OF ALKALI METALS IN CONTACT WITH GLASS—AS DETERMINED BY THE PHOTO-ELECTRIC CELL

ABSTRACT

By J. B. Nathanson, University of Illinois

As a photometer, one of the most sensitive cells made by Dr. J. Kunz, was employed. The cathode consisted of rubidium deposited by distillation on a film of silver, the rarified gas being argon. A metallic guard ring properly earthed is located between cathode and anode.

Due to conflicting literature on the relation between the light intensity and the corresponding photo-electric current, it was decided to calibrate the cell in terms of known light intensities, as determined by the aid of crossed Nicol prisms. The source of light used was a Nernst glower, due precautions being taken to exclude extraneous light. The cell itself was in an earthed metallic box. A galvanometer, having a figure of merit of 2×10^{-10} amp. per mm., at a scale distance of 2½ meters was employed to measure the current. The resulting curves obtained for various voltages, between the light intensity and the photo-electric current were found to be *not quite* straight lines, but curves which were *slightly* concave towards the illumination axis. In all succeeding determinations of reflecting powers, proper corrections were made in accordance with the curves obtained.

In the determinations of the reflecting powers of the alkali metals, the photo-electric cell was mounted on the telescope of a spectrometer, thus facilitating the determination of the angles of incidence of the light on the alkali mirrors.

Great difficulties were encountered in making the mirrors. These were made both by repeated distillations and pourings. The metal was deposited on a glass plate which formed a part of a small cell. The reflecting power of the alkali metals in contact with the glass is given by $R = \frac{O-r}{t^2(1+Or'-r-r')}$

O is the fraction of incident light reflected by the whole mirror, (metal plus glass); r is the reflecting power of the glass surface from air to glass to air; r′ is the reflecting power of the glass surface going from the glass to air to glass; and t is the transmission power of the glass plate for a single passage through the glass plate.

The values of t and r′ for various angles of incidence are given by the equations, $t = \frac{T^2+(1-R')(R'-r)}{T(1-r)}$; $r' = \frac{(R'-r)(1-r)}{T^2+(1-R')(R'-r)}$

T is the fraction of incident light transmitted by the glass plate and incident on the photo-electric cell. R′ is the reflecting power of the glass plate (both surfaces). There are no approximations in the derivation of these equations.

The investigations of the properties of the glass plates, showed that r′ is somewhat less than r. The values of r were obtained by abrading and blackening the surface of the glass plate, thus leaving only one surface effective.

Potassium gave reflecting powers of 88 per cent at 9° incidence to 89 per cent at 35°. A mirror formed by pouring the metal against the glass plate gave results coincident with those from one formed by distillation. Only one rubidium mirror has been investigated so far, its reflecting power at an angle of incidence of 9° being 76.3 per cent. This was increased to 78 per cent at 35°. Sodium gave reflecting powers increasing from 89 per cent at 9° to 91 per cent at 35°. The reflecting powers of the alkali metals therefore decrease as the atomic weight increases.

Note—So far, non-polarized light has been used. Subsequent to the report on this work the investigation was carried out, using monochromatic and polarized light. A full account of this investigation is to appear in a fall (1916) number, probably the October number) of the Astrophysical Journal.

ON THE INITIAL CONDITIONS OF THE CORONA DISCHARGE

ABSTRACT

JACOB KUNZ, UNIVERSITY OF ILLINOIS

There was first given a description of the numerous phenomena which are connected with direct current corona. The difference between positive and negative electricity appears in electrical, optical, mechanical and chemical effects. A new attempt at an explanation of some of the relations disclosed by experiments has been made. Relations between the critical electric force at the surface of the wire, the pressure of the air and the radius of the wire have been obtained. The constants in these relations are different for the positive and the negative wire. These constants have been assumed the same for both polarities in the previous theories by Townsend and Davis. Townsend's theory of collision moreover is based on experiments at low pressure, while the formula, relating to pressure, radius and critical force in the corona holds only for high pressures. The principle of conservation of energy has been applied to the ionization pressure and it is predicted that over a certain range the current should be directly proportional to the pressure increase.

This paper has been published in the Physical Review, Vol. VIII, July, 1916.

A WEHNELT CATHODE RAY TUBE MAGNETOMETER

ABSTRACT

L. A. WELO, UNIVERSITY OF ILLINOIS

The paper presents briefly the theory, description and the results obtained with a new apparatus for measuring the horizontal component of the earth's magnetic field.

A specially designed cathode discharge tube is used, equipped with an adjustable Wehnelt hot lime cathode, the whole mounted so that it is freely turned about a vertical axis. The mounting thus avoids the elimination of the earth's magnetic field for a zero reading of the deflection and the hot lime cathode gives rise to slow moving electrons so that the deflection recorded on a photographic plate is of a measurable magnitude. The deflection is compared with that produced simultaneously by a known magnetic field due to a circular coil so that the use of electrostatic plates is not necessary and making the results independent of the ratio e/m.

Papers on Geology and Geography

A GRAPHICAL METHOD OF DETERMINING THE AVERAGE INCLINATION OF A LAND SURFACE FROM A CONTOUR MAP

JOHN L. RICH, UNIVERSITY OF ILLINOIS

One of the most significant elements of geographic environment is the slope or inclination of the land surface. On it depends, in a large measure, the rate of run-off of the precipitation; the rate of erosion; indirectly, the character of the soil; and finally, the possible utilization of the land for agriculture. In connection with problems of water supply and flood control, a determination of the average inclination of the land surface is of vital importance to the engineer.

In geographical descriptions of a region we seldom find any quantitative mention of the inclination of the surface. The more recent descriptions commonly state the stage in the erosion cycle, and some of them give an indication of the average relief, but these are not sufficient, in all cases, to convey a definite idea of the topography. The description of such a region would, obviously, be improved by adding to the discussion of its stage in the erosion cycle and to the mention of its average relief a statement of the average inclination of its surface.

By the average inclination of the surface of a region is meant an average in which the inclination of each individual portion is weighted in proportion to the ratio which its area bears to that of the whole. Stated mathematically, the formula[1] is:

$$B = \frac{B_1 g_1}{G} + \frac{B_2 g_2}{G} \cdot \cdot + \frac{B\ g_n}{G}$$

where B is the average inclination of the region; B_1, B_2, etc., the average inclination of the individual portions; g_1, g_2, the areas of the individual portions; and G the whole area.

The principle heretofore used for obtaining such a weighted average is that published in 1890 by Finsterwalder.[2] This writer shows that the sum of the lengths of the contour lines on a map multiplied by the contour interval, reduced to like units, and divided by the area gives a result which is as near

[1]Penck, A., "Morphologie der Erdoberflaeche," I. Buch, s 47. Stuttgart, 1894.
[2]Finsterwalder, S., "Ueber den mittleren Boschungswinkel und das wahre Areal einer topographischen Flaeche." Sitzber. K. Ak. der Wiss., Math.-Phys. Kl., XX, 1890, s 35-82.

to the true value of the average inclination as can be obtained. The accuracy of the result depends on the contour interval, on the faithfulness with which the topography is represented on the map, and on the accuracy of the measurements of the lengths of the contours and of the area.

Finsterwalder's method is doubtless the best that can be devised for maps on which the contours are few, far apart, and moderately smooth, but it is very laborious and subject to considerable inaccuracy of measurement when applied to maps on which the contours are closely spaced.[3] There are many occasions when a less laborious method, even if less accurate, is desirable, and when the graphic method here proposed should prove useful.

The graphic method is based upon the principle, demonstrated by Finsterwalder[4] that the tangent of the angle of the weighted average inclination of a profile line is the arithmetical sum of its acclivities and declivities divided by its projected length.

In accordance with this principle, the tangent of the angle of average (weighted) inclination of a meandering profile drawn across a map would be equal to the sum of all the acclivities and declivities divided by the projected length of the profile. Such a profile, if drawn across a map in such a way as to be at all points at right angles to the strike of the surface, (crossing all contours at right angles) would permit the determination of the actual average inclination of the land surface along the line of the profile. A network of these meandering profiles, all drawn at right angles to the strike of the surface at every point, furnishes a means of determining the average inclination of the surface of the region with a degree of accuracy which, as will be shown in the following paragraphs, depends on the nature of the topography and on the number and locations of the profiles.

In practice it is not necessary actually to draw the profiles. The operation is carried out graphically as follows: with a straight edge of paper and a sharp, hard pencil, begin at some point chosen at random in the area to be measured. Lay the

[3]A map-measure, a self-recording toothed wheel so constructed as to turn freely on a pivot, is on the market and will be found very useful for making linear measurements of meandering lines such as contours.

[4]Loc. cit.

paper edge perpendicular to the contours, and, by noting the contour intersections, count and add together the differences in elevation, both positive and negative, which one would encounter in traveling along the line of the paper edge. Continue thus to a point where the contours change direction. Without removing the paper, pivot on the pencil point and turn the paper until it is once more perpendicular to the contours. Proceed as before. Continue thus until the limits of the area to be measured are reached, always keeping the paper edge at right angles to the contour lines and counting and adding arithmetically all differences in elevation, whether positive or negative. Choose another point and repeat the process, continuing to add distances graphically along the paper edge, and to record the total "ups" and "downs" of the profiles. When the map has been sufficiently covered, scale off the total distance represented along the paper edge, find the sum of all "ups" and "downs," and divide the latter by the distance. The result is the tangent of the angle of average inclination of the surface. As a concrete example, suppose that the total length of the profiles is 10 miles and the sum of the ups and downs is 6630 feet, then $\frac{6630}{10 \times 5290}$ =tan. angle of inclination, or, stated in another way, an inclination of 6630 feet in 10 miles$=\frac{6630}{10}=$ 663 feet per horizontal mile.

To compute graphically the angle of inclination, express both quantities in the same units; plot the sum of the ups and downs as a perpendicular line at one end of the line representing the length of the profiles; draw the hypothenuse, and measure the angle with a protractor.

The accuracy of the results obtainable by the proposed graphic method obviously depends on (a) the character of the topography, and (b) the completeness with which the various topographic units in the region find weighted expression in the profiles. In general, the closer the net of profiles, the more accurate the result. On topography with moderately uniform slopes, such, for instance, as that of a maturely dissected plateau, a very close approximation of the average inclination of the surface may be obtained in a few moments from a very few random lines. On topography of very uneven character, some artificial device must be adopted which insures that each topographic unit shall be weighted in proportion to its area. To a certain extent this may be done by judgment alone, but some empirical method which, so far as possible, eliminates the personal equation is preferable. A method which gives good results and is here recommended, is to divide the map into large or small squares of equal area, and, by the ordinary method, run as many random lines across each square as is necessary to yield a reliable average of the inclination of its surface. Add all distances graphically along the paper edge and obtain the sum of the ups and downs in the usual way. It is essential that the same number of lines be run in each square, otherwise those in which the most lines are run receive the greatest weight in the average. This method should yield results with an error of 5 per cent or less, the accuracy depending on the care with which the work is done and the size of the squares used as units. The accuracy thus obtainable compares favorably with that obtained by Finsterwalders' method of measuring the lengths of the contours.

In judging the character of the net of profiles necessary to obtain the average slope of an area it should be borne in mind that a single measurement of a truly conical hill, or of one in which the slopes are uniform, gives a correct average, but that on a hill or valley head of circular form which has a parabolic profile, with the steeper slope at either top or bottom, the results are in error on account of the inequality of the areas having the various degrees of slope.

On most examples of mature or old topography the majority of the slopes are parabolic, but since, in general, the valley heads are the inverse of the spurs, the errors due to the parabolic curve of the surface profiles tend to balance each other where both valley heads and spurs are included in the measurements.

For certain determinations, however, such as that of the average inclination of a conical mountain, e. g., a volcano, having a parabolic profile, a special method of compensation must be employed. This may be accomplished by drawing concentric circles round the center of the mountain with radii of 1, 2, 3, 4, 5, 6, 7, 8, etc., and increasing the number of measurements in each succeeding belt in proportion to its area, namely, (if the area of the first belt be taken as one) for the first belt, one measurement; for the second, three; for the third, five; the fourth, seven; etc., in arithmetrical progression. Thus an approximately correct average may be obtained.

There are certain types of topography for which a statement of the average inclination has little meaning from the geographer's standpoint, though it still retains its value to the engineer. Such are the types in which large and distinct units of area possess markedly different degrees of inclination, while each by itself is relatively uniform. The till plains of central Illinois are examples. Broad, flat uplands are cut by narrow, steep-sided valleys. A statement of the average inclination of such a surface has small geographical value. What is needed is a distinction of the two areas, and a statement of the average inclination of each, together with an indication of its area.

For the determination of the average inclination of each division of such a region, the graphic method is admirably suited, while Finsterwalder's method of measuring the lengths of contour lines is, depending on the specific conditions, either inapplicable or very complicated.

SUMMARY

In connection with several lines of investigation a statement of the average inclination of a land surface is desirable. The best method formerly used is, in many instances, slow and extremely laborious, and is subject to considerable errors of measurement. The graphical method here proposed is simple and easily and quickly applied. Its accuracy depends somewhat on the character of the topography, and is, to a large degree, proportional to the number of measurements taken.

It, therefore, serves either for quick, rough determinations, or for those in which the maximum accuracy is required. By the use of a close network of small squares the method may be made to compare favorably in accuracy with its competitors at a considerably lower labor cost.

PRESENT CONDITION OF THE OIL INDUSTRY

Fred H. Kay, State Geological Survey, Urbana

The remarkable change which occurred in the oil industry during the latter part of 1915 is brought very close to a large part of our population in the steadily increasing price of gasoline, and it is pertinent at this time to look into the causes which led the industry from stagnation and low prices during the latter part of 1914, to unprecedented activity and high prices during the autumn and winter of 1915 and up to the present time.

Foremost among the depressing influences of 1914, was the enormous production of high-grade oil from the Cushing, Oklahoma, field. About the middle of the year, this remarkable field reached its height, and was producing daily about 300,000 barrels of high-grade crude oil, and operators were at a loss to know how to care for the output. The over production came at a time when business in the United States was depressed at the beginning of the European war, and exports were greatly curtailed if not demoralized. The general result was a great overproduction of petroleum much exceeding the demand, and a consequent reduction of prices, which led to stagnation in the industry and to a decline in all sorts of development work.

Production in 1915

In spite of the poor condition of the industry in the early part of 1915, the production for the year was 267,400,000 barrels—slightly larger than the record-breaking production of 1914. The larger total production was due principally to the continued output from the Cushing field during the first half year and the production from the Humble, Texas, pool as well as from the newly discovered pools of Texas and Louisiana.

The sharp decline of Cushing production to less than one-third of its former output, the better business conditions in the United States, the increasing foreign and domestic demand for gasoline and motor spirits together with facilitated export conditions, ushered in a new era beginning September 1915. More petroleum was marketed, stocks held in tanks were drawn upon, and refiners began to see that the increasing demand would necessitate the discovery of new production of high-grade crude oil. Prices rose rapidly and at the present time there are but few states in the Union where active prospecting for new fields is not being conducted.

PRICES

During the latter part of 1914, Pennsylvania oil sold at $1.35 The same oil is now $2.35 per barrel. Kansas and Oklahoma oils sold at 40 cents, and now bring $1.30 per barrel. Regular Illinois oil sold until September 1st, at 84 cents per barrel, but now commands $1.62. Oil from the Plymouth field, a newly discovered area in the western part of Illinois, sold during a large part of last year at 42 cents per barrel, but now sells at $1.42.

GASOLINE INDUSTRY

Gasoline now costs the consumer 9 cents more per gallon than in July, 1915. The steady decline in the production of the high-grade oil at Cushing resulted in a demand for similar oils from other parts of the United States and immediate higher prices for this product. Although stocks of crude oil at the end of 1915, aggregated 45,000,000 barrels more than at the beginning of the year, operators were holding their stored product because of the certainty of higher prices. The constantly increasing demand for gasoline is generally attributed to the increase in the number of automobiles, gasoline engines, and to a wider general use of this product. The domestic consumption in 1915 was 25% larger than in 1914, and a similar increase is expected for 1916. It is estimated that in 1915 there were 2,100,000 automobiles in the United States. The manufacturers of these machines estimate that each automobile uses 500 gallons of gasoline per year, a total of 1,015,000,000 gallons for automobiles alone, which represents a 77 per cent increase in 5 years. All the other uses to which gasoline is put probably increase the total amount used in the United States to 1,500,000,000 gallons per year.

Two general sources of gasoline furnish the entire supply. Distillation of crude oil for the lighter constituents furnishes most of the present supply, whereas casing-head gasoline is becoming more and more prominent. The latter product, which until ten years ago was allowed to waste, consists of the lighter oils in natural gas. It is extracted by subjecting the gas to great pressure and then allowing it to expand and cool. The gasoline condenses at the same time. The richness of the gas varies from about two to six gallons of gasoline per 1,000 cubic feet of gas.

In 1911, 7,425,000 gallons of casing-head gasoline was manufactured in the United States, whereas in 1914 42,652,-000 gallons of this material found its way to market. It is estimated that with the same per cent of increase the year 1915 showed about 75,000,000 gallons of casing-head gasoline which was an absolute loss until a few years ago. However important this source of gasoline is, there remains a demand for about 975,000,000 gallons which must be supplied from crude oil.

In 1915 about 108,000,000 barrels of high-grade crude oil was produced. In order, then, to furnish the supply of gasoline, it is necessary that a barrel of high-grade crude oil under older refining methods must produce about eight gallons, nearly 25 per cent of gasoline. With most crude oils this per cent was about the maximum, but recently new methods of refining have been introduced; namely, the Rittman, Burton, Washburn, Seeger, etc., all of which depend on the theory that crude petroleum consists of a mixture of molecules in which the smaller ones are gasoline, naptha, etc.; the larger ones kerosene; still larger ones, the lubricating oil, and so on down to the heavy residue. The new processes depend on breaking up the larger molecules into smaller ones by heat and pressure, either in gaseous form or as a liquid. It has been found that the heavier residue which is left from present methods of refining may be divided by extreme heat and pressure into gasoline and heavier liquids.

There is at the present time and probably will continue to be an excessive demand for gasoline in excess of the kerosene and lubricating oils. The new processes will probably enable the refiners to produce a very large per cent of the gasolines for which there is an excessive demand, and to leave only small amounts of the heavier products which are now a drug on the market. These processes, together with the rapid in-

Figure 1—Typical scene in the Ozark Hills, Pope County, Ill.

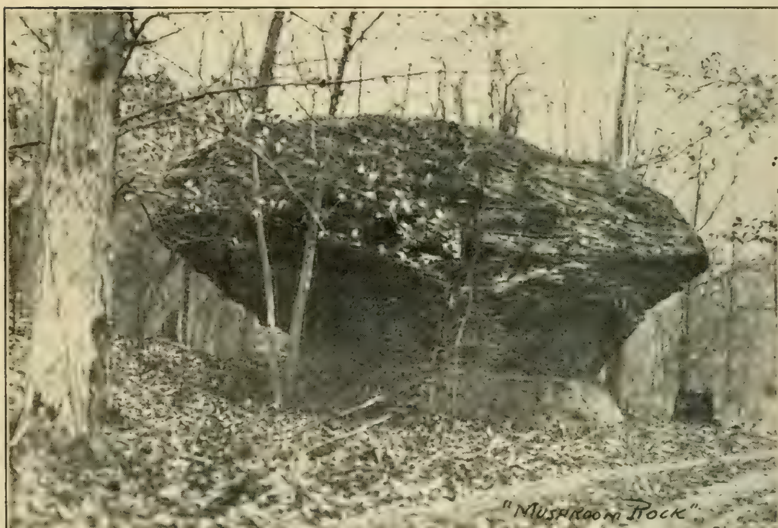


Figure 2—Mushroom Rock in valley of small stream leading from Clarida Spring into Bay Creek, Pope County.

crease in the amount of casing-head gas produced, will probably benefit the consumer in steadying the price of this important commodity. Until the new methods of refining are in operation, however, and unless a large amount of new production is discovered, and if the present chaotic conditions in Mexico are not abolished at an early date, it is very likely that the price of gasoline will continue to rise for the present. It is very likely that an unprecedented amount of prospecting will be carried on during the coming warm season, and it would not be surprising if a large amount of new production is discovered. Much attention is now being turned to the states of Wyoming and Montana and practically every favorable geological structure will be tested during the coming year.

The recent congressional investigation has emphasized the fact that the constantly increasing demand for motor fuels and the decline in high-grade production are directly responsible for the present high prices of gasoline.

If the American inventor were not capable of extracting larger and larger percentages of gasoline from all types of crude oil, the gas engine industry would now be facing most serious problems.

Prosperity with its demand for luxuries is now laying a direct tax on the American public.

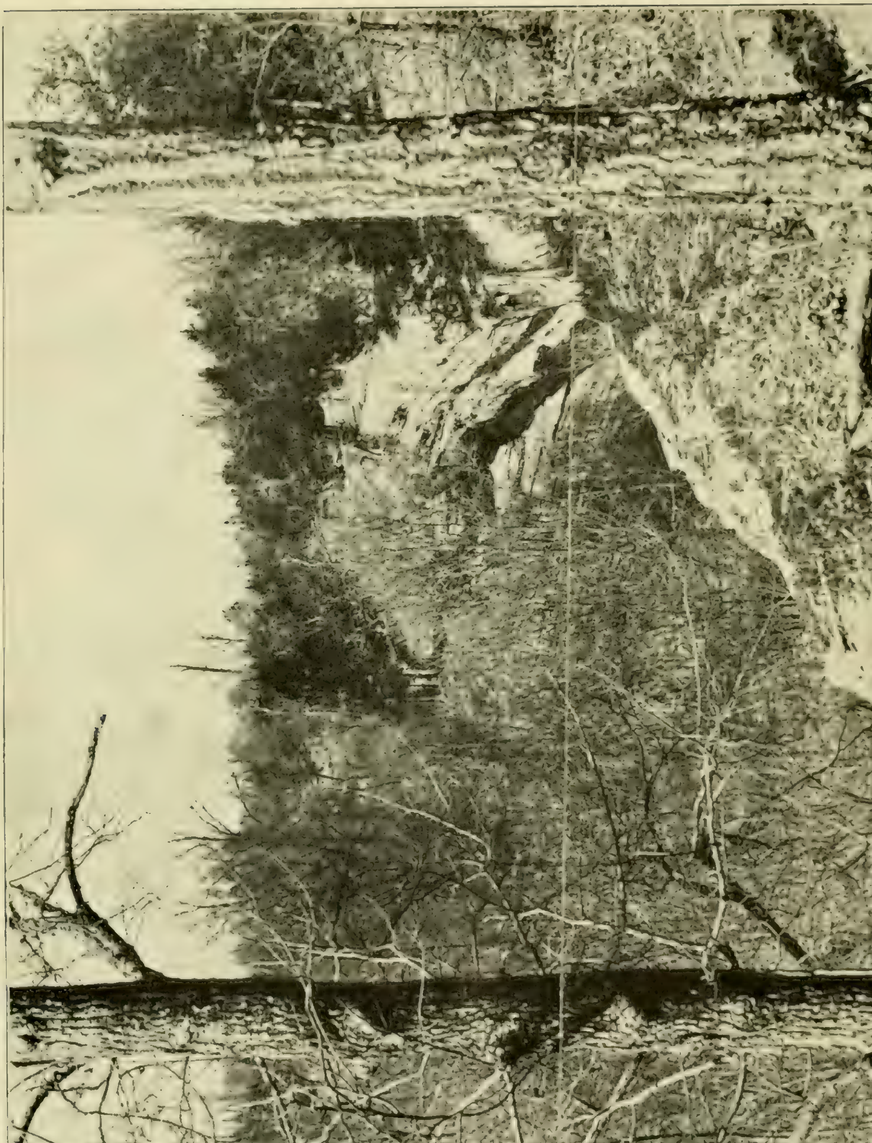
THE VARIETY OF PHYSIOGRAPHIC MATERIAL IN A FEW COUNTIES OF SOUTHERN ILLINOIS

CLARENCE BONNELL, HARRISBURG TOWNSHIP HIGH SCHOOL

Mention of the two southern tiers of counties of Illinois to an audience from the more northern counties, calls up as many mental pictures as the blind men had when seeing the elephant. Whether the picture be one of swamps, mountains, floods, canons, rich farm lands, rocky hills, meandering streams, rushing torrents and cascades, rain unceasing, drought, perfect autumn weather, or fruit-killing frosts of April, depends entirely upon the time and point of contact. No part of the state has a more varied or changeable climate, Chicago not excepted. What is true of the climate is more true of the physiography.

In the counties of Saline, Gallatin, Hardin, Pope, Massac and Johnson, the variety of natural phenomena is not surpassed by any equal area in the state. The Ohio river on the border alternately cuts through highlands and crosses lowlands.

Near it and its tributary, the Wabash, lie strings of lakes, the remnants of former meandering channels. Two other tributaries, Bay Creek and the Cache River, flow in opposite directions from their common source in the cypress swamps north of Massac County, but occupy, with the swamps, the old bed of a river walled in by high bluffs and with a valley large enough to carry the Ohio of today. In fact, in time of floods, a distinct current from the Ohio flows up the Bay valley, through the swamps, and on down the Cache. The Saline River, except in its upper tributaries, sluggishly meanders through a rich farming country elevated but little above the Ohio. Overlooking these valleys are the Ozark mountains or hills, a dissected plateau, rising so abruptly that a change of nearly 600 feet in elevation may be made in a half hour's climb. Notably, along the Gold Hill axis in southeastern Saline County and at the Old Stone Fort, a few miles further to the west, and near Parker City, upheavals resulting in faulting and bending followed by rapid erosion have brought to view massive sandstones and limestones. These bluffs, topped with the conglomerate sandstones or millstone grit, command a view of the whole county. Weathering has produced curious forms and many overhanging ledges. Strata, tilted as much as 40° in places, tell the story of the mighty forces at work in the past. In the elevated limestone section of Eagle Cliff (the "Prospect Hill" of Worthen) the entrance to a cave commands a view of a large part of two counties. This cave probably had its origin in the upheaval which opened cracks which have since widened into extensive chambers as the limestone has dissolved. The explorer needs no one to guide him back to the opening if he remembers that the strata in this "block mountain" always slope down to the east and south. Standing here on the sub-carboniferous rocks, the view for twenty miles to the northwest discloses a rolling plain lying several hundred feet below—a plain covered with glacial drift almost to the foot of the hills and underlaid with the true coal measures, the richest in the state. Frequent slips, revealed only in the many mines, tell of the extent of the disturbances that pro-



duced the cliff and raised it bodily from the depths of the earth to look out upon the advancing glacier as it wavered and then retreated, leaving a thin sheet of drift and small boulders, not, however, to be compared in size and numbers with those of central Illinois.

From this point south, through Hardin and Pope counties, massive cliffs or ridges, usually the direct result of erosion, are always in sight. In Hardin County, near Elizabethtown, an extensive limestone region is honey-combed with subterranean passages, as is evidenced by the many sink holes, some of which are obstructed at the outlet and now form small lakes or ponds. One such passage opens into the river bluff at Cave-in-Rock and forms the famous cave about which cluster much tradition and early history of the region. The enterprising manufacturers of St. Jacob's Oil, years ago, painted their sign in six-foot letters above the entrance to attract the eye of the traveler on passing boats. Though obstructed by a sink hole, 150 feet from the mouth, its arched entrance and rocky walls make it a wonder to those who do not read among the names painted and carved on its interior, the deeper written history of its origin.

This is a country much as nature left it. Broad wheat fields cover the level ridge tops, and fertile corn fields, the valleys. The iron deposits, worked in war times, lie too far from railroads for exportation. The greatest fluor spar mines in the land, at Roseclaire and Fairview, are only beginning to be developed. Ranges of cement limestone and close textured sandstones lie yet untouched. The two thick veins of coal in Saline and Gallatin counties, now worked from nearly two score mines, are scarcely disturbed as yet. Man can destroy in centuries but a small fraction of what nature has already destroyed of her own handiwork by the agencies of erosion, as is displayed in the hundreds of canon-like valleys of these counties. Grand Pierre Creek from its source to its mouth is deserving of a week's study of erosion. In one corner of Saline County, up the rocky stream bed of Mud Spring Hollow, across the ridge and down the bed of Beech Hollow, up Stillhouse Hollow, and then down the Little Eagle Valley, in a single day's hard tramping, the student may see within these narrow cliff bordered valleys all the forces at work which have made the mighty Rockies of the West.

Nowhere in Illinois is the enormity of Nature's work in depositing and then removing great quantities of rock better shown than in this same vicinity at Womble mountain, a mesa-like rock of reddish sandstone, having an area of about ten acres, being slightly split diagonally across, displaying fore-set beds and other evidences of shore lines, and standing far above the surrounding valleys. The even sky line, as seen by looking from it across twenty miles of the Ozark Hills into Kentucky, together with corresponding strata across the valleys, make it clear that these same valleys, once filled with rock strata laid down under the sea, have been carved out by running water and that the process still continues.

The perpendicular walls show two degrees of weathering, one of long continuance giving a long talus slope on all sides, with "slide rock," such as Hornaday describes in the Canadian Rockies, and another more recent, wherever huge blocks have broken off and rolled or slid down the old talus slope. One of these, 225 feet in circumference and 35 feet high, locally called "Table Rock," has slid down a hundred feet, remaining horizontal. The east and south sides show little weathering, as also the corresponding niche in the cliff above, from which it came, while the west end and north sides are rugged, corresponding with the undisturbed portion of the cliff. Large trees grow between this huge block and its former position. There is nowhere much evidence of gradations between these two stages of weathering over a carefully studied region in three counties. In many places portions of cliffs have fallen off, but none more recently than the beginning of the growth of 10 and 15-inch forest trees now growing where the mass passed as it slid. These facts, together with the fact that in this hill region of Illinois and nowhere else in Illinois, there is common knowledge of a traditional nature among the native stock of hill dwellers concerning the great New Madrid earthquake of 1811 and 1812, have led me to question whether there could be any connection between that earthquake and these huge falls of rock.

Follow me for one day, starting before daylight, for an 18-mile drive from Stonefort or a 10-mile drive from Ozark or Simpson to the Belle Smith Spring. The nearest way is to follow the rocky stream bed of Hunting Branch for the last

three or four miles to its junction with Bay Creek near the spring which is not remarkable except that it is near a popular camping place. A better way is to drive over a good road to the head of Clarida Branch and pitch camp under the overhanging cliff near the cool waters of Clarida Spring, which is only a few hundred feet from the head of this valley. Here the water, for a few minutes only after a rain, flows in torrents from an extensive rock basin above and over the cliff, which overhangs as much as 30 feet.

Just beyond the cascade we climb upon fallen rock masses onto the "Indian Ladder," a cedar trunk which has positively remained loose in this place for three generations, and, according to tradition, was there when the first white men came. Cross over the ridge to the left of Clarida Branch to another valley and enter the great Sand Cave, a dome-shaped room in the solid sandstone cliff whose interior dimensions are 142x116 feet, and whose arched roof is 21 feet high. A large drove of horses, mules and cattle finds shelter here from cold in winter and from heat in summer. Situated near any large city and floored, it would yield a fortune as a dancing hall, always dry, always cool, but never cold. Along the curving cliff at most places the softer rocks below have disappeared, but, close to the cave opening, for 150 feet, the overhanging cliff has fallen off and lies a crumbling mass on the slope below, leaving the smooth new face of the cliff in view. And the trees have grown since the cliff fell.

Back over the ridge and on down Clarida Branch we pass toad-stool formations imitating those in the Garden of the Gods, but mostly hidden in the thick brush. A balanced rock 40x50 feet and 35 feet high stands on a triangular base only 20x20x10 feet, but is too densely hid by shrubs and trees to be photographed.

Clarida Branch joins Bay Creek near the Belle Smith Spring. Bay Creek, after it leaves the hills and enters the old river valley, for 33 miles, is very sluggish and muddy and has a current upstream in flood time, as mentioned before. In the upper seven miles of its course it has a fall of 300 feet, and is clear and bordered by perpendicular bluffs. A few hundred feet above where it is forded at the mouth of Clarida Branch, the left bank has a steep wooded slope to one of the characteristic curving bluffs. At one place this bluff was deeply undercut, as at the Sand Cave and Clarida Springs, and at many other places where the millstone grit appears. In fact, a cave had formed. But the dome of the cave fell in and most of it was washed away, so that the water from the slope above now falls over a new cliff further back and runs under a natural bridge whose arch is 25 feet wide, 16 feet thick and whose under surface is 24 feet from the bed below. The span is 150 feet in the clear. On three different occasions, armed with the best of cameras, but not with climbers and axes, we have tried to photograph it successfully, but it is too big and too high up the slope, with too many trees in front, to be readily photographed.

There is abundant natural material in these few counties to illustrate all the essential points in a high school course in physical geography. Much valuable material is lying unused because it has never been put into the books for those who are not near it, and because it is not appreciated by those who do live near it.

THE PRESENT STATUS OF THE DOLOMITE PROBLEM

ARSTRACT

By Francis M. Van Tuyl, Colorado School of Mines

There is convincing evidence that the great majority if not all of the important sedimentary dolomites have resulted from the replacement of limestone through the agency of solutions bearing magnesia. Most of the data favors the view that the alteration took place before the limestones emerged from the sea. But the conditions under which this was effected are not certainly known.

(Complete paper published in Science, N. S., Vol. XLIV, No. 1141, November 1, 1916.)

THE GENESIS OF THE SEDIMENTARY ROCKS—AN UNDEVELOPED FIELD IN GEOLOGY

ABSTRACT

By Francis M. Van Tuyl, Colorado School of Mines

The value of more careful examination of the sedimentary rocks both in the field and in the laboratory is emphasized. Critical study of these will undoubtedly throw a flood of light upon many problems connected with their origin, and will furnish additional data regarding the paleogeography of past geologic ages.

(Complete paper published in Proceedings of Iowa Academy of Science, 1915, under the following title: "The Lithogenesis of Sediments.")

THE CHLORITIC MATERIAL IN THE ORES OF SOUTHEASTERN MISSOURI

ABSTRACT

C. S. Ross, Geological Survey, Washington, R. C.

In the Bonneterre formation of southeastern Missouri a mineral occurs, associated with the lead ores, that has long been referred to as "chloritic material." Spurr has casually referred to it as glauconite.

A microscopic study of this mineral shows that its optical constants are very different from those of chlorite. An approximate test for potassium indicates the presence of about 9 per cent of K_2O.

From the foregoing it is evident that the mineral cannot be chlorite, but must be glauconite, since all its optical properties agree with those of the latter mineral.

A more extended account of the Missouri glauconite was published in "Economic Geology," Vol. XI, No. 3, April-May, 1916.

LATERAL EROSION IN THE UPPER ILLINOIS VALLEY BY THE CHICAGO OUTLET

ABSTRACT

Gilbert H. Cady, University of Illinois

The effect of the lateral erosion of the great stream known as the Chicago Outlet upon the upper Illinois Valley has been to truncate the normal cusps and indentations and to straighten the valley wall. The effect upon the lateral (tributary) valleys has been varied. Some valleys have been dismembered, as at Starved Rock, and others have suffered incision so that they have been cut in two. Where Illinois Valley crosses the LaSalle anticline the unusual resistance of the St. Peter sandstone, presumably due to the folding, has resulted in a conspicuous narrowing of the valley. In general there is a definite relation between the character of the country rock and the width of the valley.

THE NEW RICHMOND SANDSTONE OF NORTHERN ILLINOIS

ABSTRACT

Gilbert H. Cady, University of Illinois

The New Richmond sandstone is the oldest known formation outcropping in Illinois. This sandstone is a member of the Prairie du Chien group (lower magnesian limestone.) As an aquifer it has an importance in certain parts of the state comparable to that of the St. Peter sandstone. Its distribution can be better indicated and its character better described han formerly because of recent drilling near LaSalle and because of the recent discovery near Franklin Grove of the only known outcrop in the state.

THE STRATIGRAPHY OF THE KINDERHOOK GROUP IN WESTERN ILLINOIS AND MISSOURI

ABSTRACT

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Strata of the Kinderhook group, comprising the lowermost division of the Mississippian system in the central Mississippi Valley states, outcrop in southeastern Iowa, western Illinois and around the Ozark highlands of Missouri into northern Arkansas. The character of the rocks in different parts of this area and the fossil faunas which they contain afford the data for a study of the very interesting but complex physical history of the region at this time.

Recent examination of the Kinderhook beds across the state of Missouri, with careful study of their faunas, throw light on important stratigraphic problems and necessitate some changes in previous conceptions of the Kinderhook.

The Kinderhook rests with distinct unconformity on older formations, which vary in age from early Upper Devonian to the Lower Ordovician. It is similarly delimited at the top in many places, succeeding beds containing a distinct new fauna which may be traced throughout the Mississippian area. Within the Kinderhook a number of changes in the relation of sea and land took place.

EROSION FEATURES OF THE MESA VERDE

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The Mesa Verde is a part of the extensive plateau region of the southwest, and, in general, possesses the usual plateau characteristics. Its history is so closely connected with that of the larger physiographic unit that the area scarcely can be considered, adequately, except in its larger relationship. This larger "Plateau Province," as the area was named by Powell[1], is roughly circular with its center a little west of the juncture of the four states, Arizona, Utah, New Mexico, and Colorado.

[1]Dutton, C. E.: Second Ann. Rep't. p. 50, 1880-81.

The whole comprises an area of about 130,000 square miles, an area almost equal to that of Ohio, Indiana and Illinois. (134,000 square miles.) About 45,000 square miles of this is in Arizona[3], a similar area in Utah, about 20,000 in New Mexico, and about 15,000 in Colorado. Powell in 1879, impressed more by the depth and ramifications of the canyons, applied the descriptive term of "Canyon Lands" to the more dissected part. These names suggest the chief characteristics of the region, great elevation, general horizontality of the strata, and an unusual development of canyons. The name "Colorado Plateaus"[4] in more recent literature is descriptive of the divisions of the main plateau into many minor natural units.

The Mesa Verde, one of these units, is located on the extreme eastern boundary of the Plateau Province in southwestern Colorado. It is cut off from the main plateau by the Rio Mancos Canyon which forms the southeastern and southern boundary. The mesa terminates elsewhere in an abrupt escarpment, 1,000 to 1,500 feet high, overlooking the so-called Montezuma Valley which separates it from the Ute mountains on the west, and the Dolores Plateau on the north. To the northeast, close by, are the LaPlata Mountains. The mesa has an area of about 200 square miles and is fairly well known because of its ethnic interest. A part of it was set aside by an act of congress in 1906, establishing the Mesa Verde National Park, "for the preservation from injury or spoilation of the ruins and other works and relics of prehistoric or primitive man.[5]" This paper deals primarily with this area set aside as a national park.

Although the general characteristics of the mesa are best understood in its relationship with the larger plateau, the more special features, however, are due to local conditions. One of the most prominent of these is the extremely variable semi-arid climate. The mesa is sufficiently near the La Platas to get enough precipitation to support a shrubby growth of oak, pinyons, and cedars; and thus the name Mesa Verde was applied because of the contrast with the more desert region to the south and west. However, the contrast with the lower

[2]Second Ann. Rep't. U. S. G. S., p. 50, (1880-81). Sixth Ann. Rep't. U. S. G. S., pp. 114-117 Pls. 11 and 12 (1884-5).
[3]Robinson, P. P., 76, U. S. G. S. p. 13.
[4]Bowman, I.: Forest Physiography, p. 256.
[5]Rep't. of Sup't., 1913, p. 11.

slopes of the LaPlatas to the northeast is marked even more strongly. These slopes less than twenty miles away have sufficient rainfall to produce a luxuriant growth of vegetation. The mesa lies, therefore, on the borderline of arid and humid climates, the line separating the two, shifting according to the amount of precipitation for each year, which is extremely variable. In 1911 the precipitation for this region was more than 25 inches, as heavy as anywhere in the state, while in 1912, it was mapped as having less than ten inches, as light as anywhere in the state[6].

This great variation in the annual precipitation has a tendency to increase the amount of erosion over what it would be, did the rainfall each year more nearly approach the mean of 16.88 inches. The type of vegetation is determined by the driest years and not by the mean of precipitation for a series of years. With a rainfall of less than 10 inches in certain years, only vegetation with special provision for resisting drouths can survive. Such a vegetation has little value as a protective covering, neither is there, under such conditions, an accumulation of humus to prevent rapid run off or to aid in the disintegration of the rock.

The occasional heavy annual precipitation in this type of region does not increase the value of vegetation as a protective covering, but produces a degree of erosion which is far in excess of the normal for either a humid or an arid desert. Desert conditions for plant life are still further enhanced by the major part of the rain falling during the latter part of the growing season on a hot, parched earth when evaporation is extremely rapid. Again, the major part of the rainfall of the growing season may be concentrated in a single shower near the close of the growing season. These infrequent and violent downpours lead to a minimum of plant protection and give a maximum efficiency of the running water. The possibilities for erosion under such conditions are many times what the mean rainfall would seem to indicate. It seems hardly necessary, as is frequently done, to postulate more humid conditions to account for the unusual amount of erosion everywhere in evidence through the mesa.[7]

[6]U. S. Dept. of Ag. Weather Bur. Col. Sec. Ann. Sum. for 1911 and 1912, p. 11.
[7]Atwood, W. W.: Annals of the Assoc. of Am. Geographers, Vol. I, p. 100.

A second important local factor is the alteration of more and less resistant strata. The entire mesa is capped by the Mesa Verde sandstone, and it is into this that the numerous canyons 800 to 1000 feet deep have been cut. Only on the escarpment on the north and northeast is the underlying Mancos shale exposed. The shale is very soft and friable and erodes very rapidly. The overlying sandstone is more resistant and provides a protective capping. Although there is no permanent stream on the north to carry away the talus, nevertheless a very steep escarpment is maintained. The soft shale and the resistant sandstone capping make almost ideal conditions for cliff recession, the characteristic manner in which erosion takes place throughout the entire Plateau Province. As rapidly as the shale at the base is carried away by the wind and occasional downpour, and the sandstone undercut, there is a slumping off of huge masses of the latter, which are disintegrated and carried away in turn.

The Mesa Verde series is in itself a natural cliff former. It consists of a succession of alternating sandstones and shales. Although there is great local variation, there are in the main two great massive series separated by carbonaceous shales and thin-bedded sandstones, both the shales and thin-bedded sandstones weather with unusual ease. Some of these sandstones are sufficiently soft to be crumbled easily in the hand. The massive layers are the cliff formers. The lower massive series named the "Lower Escarpment Sandstone" by Holmes[8] is more pronouncedly massive toward the south. In the direction of the La Plata mountains it frays out more and more and does not form a distinct lower scarp as it does in the San Juan Valley as noted by Holmes. This massive layer has little effect on the topography of the area, except along the mesa escarpment where it forms the main resistant capping. The "Upper Escarpment Sandstone" forms the floor of the greater part of the mesa. Towards the south this series is unusually massive, single beds being 50 or 75 feet thick. The massiveness, however, almost entirely disappears toward the north, at least, sufficiently to have no appreciable effect on the topography. To the east in the Red Mesa and in the La Plata quadrangles the massiveness is much more pronounced as well as to the South. Cross says:

[8]U. S. Geol. Surv. of the Terr., 1875, Pl. XXXV, opp. p. 244.

"There is little doubt that the 25-foot bed of sandstone, possibly together with the strata above and below, corresponds to the 'Upper Escarpment Sandstone' of Holmes, which has a thickness of two hundred feet in the great Hogback on the banks of the San Juan river south of the Mesa Verde.[*]"

The Upper Escarpment series is very effective in controlling the character of the topography. Where it is massive the surface of the mesa is flat even up to the edges of the canyons. This is true where the massive layer is not immediately at the surface as in the southeastern part. Along the canyons it produces a vertical scarp, which is so abrupt that crossing a canyon is impossible except under especially favorable circumstances. Many miles of travel are necessary often times to reach the opposite side of the canyon. Such canyons are locally known as "rimrocked." Where the massiveness of the upper layer is absent there are no flat stretches. The inter-canyon areas are all rounded and the topography is entirely different. The line separating the two is sufficiently marked that the cattlemen have designated it as "The Break." Cattle are reported as being either above or below "The Break."

A third local factor in the erosion is the dip of the rock in relation to the stream gradient. The entire drainage is to the south with a surface slope averaging from 125 to 150 feet per mile. The dip of the strata is also to the south, and since it is slightly greater than the surface slope there is a truncation of the beds. The stream gradient is much less. The average gradient of the Rio Mancos is only 62.5 feet per mile, and is therefore about one-half the dip. This means that the cutting is always directed toward upturned edges of the strata, thus aiding materially in the rapidity with which the canons are cut.

Even with the alternation of more and less resistant layers, the stream gradients are, nevertheless, rather uniform and there is no development of rapids or waterfalls. The canyons are narrowest where the stream is cutting a resistant layer and widen out above. Since the cutting point of the resistant layer slowly migrates down stream as the canyon is deepened, the widest part of the canyon is in the upper reaches and migrates downward also. The Mancos itself is an especially good ex-

[*]Cross: La Plata Folio, p. 5.

ample. In its upper course it has cut through the entire Mesa Verde series and is developing a wide valley in the softer Mancos shale. Similarly, Morfield and Prater canyons have cut through the sandstone in the upper courses and have developed comparatively broad and open valleys.

The situation of the mesa on the border of the Plateau Province, and at the foot of the La Plata mountains is also important. The mesa on the north is bounded by a sharp escarpment averaging about 1,000 feet in height, overlooking lower country from which the Mesa Verde sandstone and the Mancos shale have been removed. This has been accomplished by stripping, a gradual recession of the escarpment due to sapping. This stripping is comparatively rapid because of the much greater rainfall in the mountain area than in the plateau country. The La Platas are regularly mapped with the areas having the heaviest precipitation in the state. Their drainage is predominantly to the southwest and erosion, therefore, is unusually active on the soft shales at the base because of the abundance and clearness of the waters.

THE CHARACTER OF THE EROSION

The erosion is predominantly by canyon cutting and by cliff recession through stripping. Erosion on the flat plateaus, except by wind, is almost negligible in comparison. Where water runs over an impervious surface the result is sheet wash. But where the soil is very porous, as on the greater part of the plateau, the absorption is rapid enough to prevent even much sheet wash. Only where the water drops over the rim rock and in the bottoms of the canyons can there be much erosion. The canyons, therefore, are deep and narrow, the upper end usually box-like. The erosion is headward, up slope, toward the source of the supply. Since the slope is all in one general direction, the growth of the canyons is in one direction, also, producing the parallel arrangement of canyons so conspicuous on the mesa.

The box-like endings of canyons is especially noticeable in the small canyons where the headward cutting now is extremely slow. In these small canyons the massive layer is well supported on the sides, and the undercutting into the softer layers is sometimes several hundred feet. Many of these cavern-like openings were used by the ancient inhabitants of the region as homes, who built walls across the front, appropriating the upper massive rack as a roof. This is true of all the canyon ruins, the best example being Cliff Palace.

The other characteristic method of erosion in the plateau country is by cliff recession through stripping. The general degradation of the Plateau Province is accomplished predominantly by the erosion forces acting upon the almost vertical edges of the strata where weathering, and wash, and wind is especially effective. This sapping has gone on to an unusual degree on the northern escarpment of the mesa where conditions are very favorable. The almost vertical escarpment of about five hundred feet of Mancos shale, capped by a heavy sandstone, gives almost ideal conditions for cliff-recession. As rapidly as the softer shale is carried away below, huge fragments of sandstone slump off, making immense talus heaps which in the aggregate resemble, somewhat, landslide topography. These heaps are comparatively short-lived because there is so little vegetation to protect them. The present mesa is only a skeleton of what it was originally. It has been cut up into many narrow strips by deep canyons which roughly parallel each other. These canyons starting at the Mancos in the south have gradually worked their way headward until they have cut through the entire present length of the mesa. This cutting has gone on to such an extent that the canyon areas are about equal to that of the remaining plateau surface. From the standpoint of travel the region is as rough as most mountain areas of the west. The canyon walls are the dominating elements of the relief, a relief produced by downward departures from the general level, instead of an upward departure as is common in mountainous areas. This gives an uncommon type of topography. None of the canyons at the present time have running water except during very severe showers. They are all aggrading in the main and show considerable fill. Wells sunk to the bottom of this loose material usually have sufficient water to supply the stock foraging in the upper canyons. These wells show from thirty to seventy feet of loose wash material, according to Mr. Prater, who had the wells sunk. If his report may be relied upon, and we believe it may, the canyons formerly were much deeper than now and must have carried much more water. This points either to a much more arid condition at present or to a cutting off of the water supply from the north. The latter seems entirely adequate to explain all the present canyon features.

There can be little doubt that formerly the mesa surface reached much farther to the north and northeast extending even over the Dolores Plateau[10] to the north and probably over the La Plata[11] region to the northeast. After the doming of the La Plata Mountains in Tertiary times active stripping began. The higher areas because of greater precipitation and steeper stream gradients suffered greater erosion than the regions farther out, and the softer formations were readily stripped from the area. This stripping continued from the mountains plateauward, thus gradually removing the upper parts of the valleys, and causing the plateau escarpment to migrate from the mountains. Facts of various kinds support this view. (1) The talus of Mesa Verde sandstone is found all along the northern escarpment for a distance of three or four miles from the foot of the mesa. This material is not waterworn and shows no evidence of landslide. The nearer the mesa the larger and more numerous these talus heaps become. These show the recession of the mesa front for this distance at least. (2) Mesa canyons also give evidence of having extended farther to the north. All the main canyons cut through the entire mesa, giving a serrated appearance to the north scarp. Since the entire drainage is still to the south, the canyons, evidently, have been beheaded by a long continued cliff-recession. Morfield canyon offers the best example of this. The upper canyon divides into two branches forming a Y. The recession of the scarp has gone on to such an extent that both branches have been almost entirely removed, leaving a semicircular cone of Mesa Verde sandstone surrounded entirely by Mancos shale. What is now mapped as Lone Cone is, therefore, only the last remnant of an inter-canyon strip. The entire drainage is to the south except at the very edge of the escarpment. The recession of the cliff is sufficiently rapid to prevent the development of a drainage in the opposite direction as would seem most natural, especially in those canyons cut into the shale in their upper courses. (3) The entire canyon system implies an enormously greater amount of water than now falls on the mesa.

[10]Cross: La Plata Folio, p. 4.
[11]Cross: La Plata Folio, p. 10.

Where the area within steep sided canyons is equal to or even greater than inter-canyon areas, there must have been a great amount of water to do the cutting , and this water must have fallen outside the area where the canyons were cut. (4) At the present time all the canyons show an aggraded condition. The occasional heavy downpour serves only to carry the loose detritus down the slopes into the canyon below where most of the water immediately sinks into the porous material at the bottom of the canyon. Such material in former times must have been carried away by the water coming into the head of the canyons.

(5) The Mancos river rising in the La Plata mountains flows southwest through a broad open valley for about fifteen miles, then turns to the south, entering the plateau region by a canyon 1500 or 1600 feet deep. It flows south and then southwest in a deep canyon, reaching open country again, having separated the mesa completely from the rest of the plateau. This direction of flow can be explained only by considering the river as a stream whose course was determined at the time the general mesa level extended over the present intervening lowland. Especially must this be so, for there is much lower country to the east through Cherry Creek or to the west through the broad Montezuma Valley along the north and west sides of the mesa. The latter would seem a much more natural course. Furthermore large boulder beds four to six feet thick are found upon the mesa along the Mancos Canyon. These boulder beds record the time the present Mancos flowed over the top of the mesa.

The principal features of the mesa, therefore, are purely a product of its erosional history. Its former great extension to the north and to the northeast served to bring sufficient water for the development of an unusual system of deep canyons. The canyon cutting, gradually, became less and less marked with the decrease of running water, until at the present time there is not enough water to carry away the slight wash from the canyon walls. Canyon erosion except in the Mancos, practically has ceased throughout the entire mesa because the water supply has been cut off. On the other hand, erosion by cliff recession is extremely active. Unquestionably a large part of the mesa has already been removed and with it the upper end of all the main canyons, leaving the remnants as a record of conditions long since past.

Papers on Zoology, Entomology and Medicine

OBSERVATIONS ON SEASONAL DISTRIBUTION AND LONGEVITY OF SOME ACANTHOCEPHALA FROM FRESH-WATER HOSTS

ABSTRACT

H. J. Van Cleave, University of Illinois

In collecting fresh-water Acanthocephala the writer has been impressed by the varying degrees of infestation of certain vertebrate hosts at different times of the year. A search of the literature has furnished no accurate information on this subject, so it seemed worth while to investigate the question, especially since Linton in a recent paper has rather summarily dismissed the topic with a brief generalization. Records of the occurence of three species belonging to the genus Neoechinorhynchus have been studied with the following results:

1. Seasonal distribution of fresh-water Acanthocephala varies in different species. No general statement can be made to apply to the entire group.

2. *N. emydis* occurs in turtles from some localities at all seasons of the year. The same individual host bears a mixture of mature and immature parasites. This indicates that the host is constantly exposed to sources of infestation. There is no cyclic change in the degree of infestation from month to month.

3. *N. gracilisentis* enters the intestine of the gizzard-shad in early fall and continues to develop until April or May, when it attains sexual maturity and is finally expelled. During the summer months the host is not parasitized by this species.

4. *N. longirostris* infests the intestine of the gizzard-shad in the summer, reaches full sexual maturity in mid-winter, and disappears entirely in spring and early summer.

5. The demonstrable presence of a seasonal cycle in the life history of a parasite involving two or more hosts is dependent upon: (a) longevity of the parasite in the final host; (b) extent of the time in which infestation of the final host

may occur; (c) length of time required for development of the larva in the intermediate host; (d) seasonal changes in the food habits of the final host, or active migrations of the host to and from sources of infestation.

RESISTANCE AND REACTIONS OF FISHES TO POISONOUS POLLUTING SUBSTANCES FROM THE MANUFACTURE OF ILLUMINATING GAS.

ABSTRACT

By V. E. Shelford, Illinois State Laboratory of Natural History, Urbana

One of the most important sources of stream pollution viewed from the standpoint of fishes is wastes from the manufacture of illuminating gas. Illuminating gas, gas liquor, and thirty-four organic compounds representing the chief classes of compounds found in coal tar and gas liquor have been studied (carbon monoxide and carbon dioxide by Dr. Wells). All the mixtures and all but three of the single compounds (methane, acetylene, and anthracene) are very poisonous to fishes. A surprising feature of the investigation is (a) that compounds which are gases and which would be expected to diffuse out of water rapidly and leave it harmless, as, for example, carbon monoxide, remain in standing water for several weeks and continue to kill fishes, and (b) that substances which are commonly regarded as insoluble in water, such as naphthalene and benzene are among the most toxic of all. Thus considering the physical properties of these compounds (gases, volatile liquids and solids) it is obvious that the various methods of treating and recovering by-products will almost certainly deliver some poisonous compounds into streams.

Usually the toxicity of compounds is greatest for the smallest fishes, or in other words, the smaller fishes are most easily killed by the poisons. This is true down to the smallest fry studied. The relative toxicity of over thirty compounds has been determined, but as yet no attempt to determine the mini-

mum amount required to kill fishes has been made because the determination should be made as the minimum amount for the most sensitive stage in the life history of the fish. This is yet to be investigated.

Another surprising feature of the investigation is the fact that, while fishes usually turn away from detrimental substances or conditions such as carbondioxide, lack of oxygen, etc., in the case of the poisons thrown into streams by gas plants, they do not avoid the dangerous conditions but swim into them without noting them and on encountering pure water again they very commonly turn back into the poison, though death may ensue there in a short time. This strong tendency on the part of the fish renders the pollution by gas waste many times more dangerous to our supply of fish.

(A full account of this work will be found in the Bulletin, Illinois State Laboratory, Vol. XI, pp. 381-412.)

VARIATION INDUCED IN BRACHIOPODS BY ENVIRONMENTAL CONDITIONS*

ABSTRACT

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In order to study the causes of variation in brachiopods, a trip to the San Juan region of Puget Sound was made during the summer of 1915 to study the living forms, their habits of life, and their response to the physical conditions of their environment. Of four species found, Terebratalia obsoleta Sowerby was selected for study on account of its wide distribution, i.e., its presence in many habitats. Collections were made from the strand line to 90 fathoms. Complete data were taken as to depth, character of the bottom, exposure to the action of waves and tidal currents, and other physical conditions that might have some bearing on the problem.

The embryonic brachiopods pass through a free-swimming stage which lasts for several days. During this time they are carried about by the waves and currents and so introduced

into all habitats irrespective of their place of origin. Shells of young brachiopods were measured, but no variation was found in the specimens from the same habitat, or in those from different habitats.

In the older stages the shells varied, with the conditions under which they grew, from wide spirifer-like to round, almost smooth forms. The marked tendencies of the variation in form seemed to be a shortening of the shell and a rounding of the anterior angle. These characters were considered in measuring the variation. Averages were plotted which showed that there was a definite tendency toward the development of the shorter, more gibbous shell in the habitats where the animals are exposed to rough water. The same result is produced by strong wave action at the surface and by the action of strong currents below the surface.

The suggestion is offered that the slight but constant irritation or injury, resulting from thus slightly bruising the tender edge of the mantle, would cause a shrinking or puckering of the latter along the anterior margin. This would affect the shell secretion and would result in the development of the gibbous form, the shell finally presenting a rounded front to the rough water.

*See Puget Sound Marine Station Publications, Vol. 1, No. 16, pages 177-183, for complete paper.

TRANSFORMATIONS OF TRICHOPTERA

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The Trichoptera, commonly called caddis-flies, are moth-like insects, usually of small size, in which the wings are more or less densely covered with hair. They are abundant in summer near most streams and ponds, and a large number of species are known to occur in Illinois. So far as known, all the North American species lay their eggs in or very near the water. The eggs are sometimes carried around by the female after extrusion, and some workers claim that in certain species she descends into the water to lay the eggs. This observation, however, has not been confirmed. The eggs are surrounded by jelly, and often form a ring around a twig, or other small object in the water. The eggs usually hatch in four or five days, and the larvae, which are called caddis-worms, are at first free-swimmers. The larvae and their habits are the chief cause for our interest in this order, because the adults are so small, and not particularly beautiful. The larvae have the general appearance of caterpillars. They have no antennae, the legs are very long, and there are no prolegs but the anal pair. The body has a varying number of filaments containing tracheae, which serve for respiration. Shortly after hatching each larva begin to construct a case in which, with certain alterations, most of them spend their larval and pupal life. These cases are made of small bits of leaves or twigs, sand, pebbles, or any other small fragments of material available. These are fastened together with silk spun from the mouth of the larva. Some of the species of Trichopetra carry their cases around with them, while in others the cases are fixed. The larvae living in movable cases have a large swelling on the dorsum of the first abdominal segment, and usually two smaller swellings on the ventral surface. These swellings are furnished with hooks, which hold the larva in its case. The hooks on the anal prolegs are supposed to serve the same purpose, and it is certainly very difficult to pull a larva out of its case. The cases are large enough to allow for the passage of water through the tube and for the movement of the respiratory filaments. Most of these cases have a thin web of silk spun across the caudal end of the tube. When the larva moves it protrudes the head and legs from the tube and crawls along. There is also a species which bores into fallen twigs found at the bottom of streams. The larvae line the burrows with silk, and these twigs form portable cases which the larvae drag along, or which are allowed to float down stream with the current. When the twig is too long for the occupant it is girdled with a circular incision, which is deepened until the end is cut away. It is said that this is the method the larvae employ in altering the cases to suit their growth. The cases are nearly always larger at the caudal end, so the larvae cut off the small end and add to the large end.

The life history of these insects has not been worked upon sufficiently to determine the number of molts in the larvae, but it is known that many of them live through the winter as larvae and transform in June or July. When the larvae are ready to pupate they either fasten the case to some larger object, and close the other end, or they close both ends with a web of silk and frequently fasten on a pebble or a bit of stick. They are completely helpless while transforming. The pupae differ from the larvae in having larger mandibles with which they cut their way out of the case, and usually swimming hairs on the mesothoracic legs. Most of the larvae which inhabit movable cases transform to pupae which have respiratory filaments much like the larvae. The pupae have rows of hooks on several dorsal segments which hold them in the case.

The larvae, which live in fixed cases, build them in the same way. Sometimes their cases are only tubes of silk, which are found on the bottom of the stream or on the surface of sticks and stones. Others are of various shapes and generally covered with sand, pebbles, or leaves. Certain species build their cases in the form of a snail's shell, which are covered with sand, and some of these were described as snails' shells.

The larvae inhabiting these fixed cases are mostly of another type of body, which is not as strongly curved. They have no hooks to hold them to the cases, and although the majority breathe by means of respiratory filaments, a number of them breathe by means of spiracles. They pupate in much the same way as the larvae inhabiting movable cases and the pupae strongly resembles the larvae, differing in the larger mandibles and the swimming hairs on the mesothoracic legs. In some species the respiratory filaments are lost during pupation and the pupa breathes by means of one large spiracle located in the conjunctiva between the prothorax and mesothorax.

The most interesting species of larvae with fixed cases are those that spin nets, with which they catch their food. These nets are placed in the streams where the current is swift. They are usually spun somewhat funnel-shaped, so that the current keeps them expanded. These larvae often do not build a case but hide in masses of rubbish near where they have spun their nets. Those which spin cases often place them side by side, so that there is quite a colony.

The length of the pupal stage varies, but is at least two weeks. The more specialized forms which inhabit thin cases spin a thick cocoon. At the close of pupal life, the pupa cuts its way out of the cocoon and swims, back downward, to the surface, or to some solid object by which it can ascend to the surface. There it splits the pupal skin and the adult emerges. The wings dry almost immediately and the insect is then ready for flight.

FUNCTION OF THE EPIPHARYNX AND HYPOPHARYNX IN THE DIPTERA

ABSTRACT

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The epipharynx and hypopharynx of one or more species of fifty-three families of the Diptera have been studied. In all these forms the epipharynx is closely associated with the labrum and these two parts comprise the labrum-epipharynx while the hypopharynx is a separate piece in itself but it is associated with the labium in that its proximal portions join with the labium.

The structure of the labrum-epipharynx and the hypopharynx is closely related with the function of the mouth-parts as a whole. Generally speaking in Diptera with sucking mouth-parts the labrum-epipharynx and the hypopharynx are long and needle-like as in the Culicidae, Tabanidae and Asilidae, while in those having a licking type of proboscis as in Muscidae, Sarcophagidae and the Drosophilidae the labrum-epipharynx and the hypopharynx are short and blunt and only form a small part of the proboscis. Many striking modifications occur in the structure of the labrum-epipharynx and the hypopharynx, but in all the forms studied both parts are always present. Possibly the greatest reduction of the hypopharynx is found in the Borboridae. In Borborus equinus it is completely joined with the labium.

This is an abstract of a more extensive discussion on the epipharynx and hypopharynx of the Diptera, which may be found in a paper entitled, "The Head-capsule and the Mouth-parts of Diptera." This paper is to be published in "Illinois Biological Monograph."

ECONOMIC IMPORTANCE OF DIPTERA

J. R. Malloch, University of Illinois

No other order of insects equals the Diptera in diversity of habits in larval and imaginal stages. Many of the families are largely beneficial, but unfortunately the good done by them is counterbalanced by the injury inflicted by others. The essentially phytophagous families, that is those families of which the great majority of the species feed upon plants, are very greatly outnumbered by those that are scavengers or predaceous or parasitic. If we exclude those that are fungivorous, only four families remain that can be classed as even preponderatingly phytophagous—Cecidomyiidae, Trypetidae, Agromyzidae, and Chloropidae; a few of these are predaceous. It must be borne in mind that a phytophagous species is not necessarily injurious from the economic standpoint, as many species feed upon and keep in check noxious plants and may therefore be regarded as beneficial.

It is but a step from the phytophagous to the scavenging habit, and in Drosophilidae we find species that may feed upon Cruciferae, mining the leaves, or in sap exuding from trees and in vegetable refuse. A great majority of the scavengers, however, rarely feed upon living plants, the only other exception being those that are fungivorous. There are eight families that may be considered as essentially fungivorous—Macroceridae, Bolitophilidae, Platyuridae, Mycetophilidae, Sciaridae, Platypezidae, Phoridae, and Drosophilidae. Many of the Sciaridae occur in decaying vegetation, while the habits of Phoridae are remarkably diverse, some being true entoparasites.

The scavengers belong to more than a score of families. In Muscidae all the species are scavengers; but in some other families, Anthomyiidae, for example, we find phytophagous and inquiline species, though these are greatly in the minority and the family is essentially one of scavengers. The Sarcophagidae include some species that are true entoparasites, but the great majority are feeders upon decaying animal and vegetable matter. The scavengers are in the great majority of cases really beneficial, transforming dead animal and vegetable matter into such forms as can be utilized by growing plants. In reducing the bulk of putrefying substances, which, absorbed by the growing larvae, is transformed into the bodies of the resultant imagines, they remove what is noxious to man. It is chiefly when scavengers such as the common house fly contaminate our food by contact, after feeding on foul substances which are impregnated with disease germs, that there is real danger from these insects. Rarely the screw-worm fly and some of the flesh-flies deposit their eggs or larvae in wounds, either on man or on animals, and in this manner produce serious ulcerations; and the larvae of the former has been known to cause the death of persons by penetrating the brain, which it entered by way of the nasal passages. The flesh-flies and some other groups sometimes cause myiasis in man, the larvae finding their way into the stomach with food in which the flies have deposited their eggs or larvae and which has not been prepared for consumption by judicious cooking, or carefully examined so as to exclude infested portions.

We may class as true parasites nine families, some of which, as Tachinidae (*sens. lat.*), Dexidae, and Pipunculidae, are highly beneficial, and others, as Gastrophilidae, Hippoboscidae, and Oestridae, are distinctly injurious. The parasites of this order destroy many injurious species of insects, and, next to the parasitic Hymenoptera, constitute the most important check upon their increase.

Another group of highly beneficial species is that containing the predaceous forms. Two of the families which are to some extent beneficial in the larval stage—Tabanidae, and Culcidae in part—are injurious as imagines, turning their attention from insect larvae, on which they chiefly prey in the earlier stage, and giving it largely to mammals, including man. This radical change of habit is, however, exceptional, as nearly all other predaceous families in this and other orders feed upon insects in both the larval and imaginal stages. Many Syrphidae are aphidophagous as larvae, the greater portion of the species being scavengers, while the imagines are flower-frequenters.

The aquatic families, with the exception of the Sciomyzidae and Ephydridae, which are in large part aquatic, belong to the Orthorrhapha. With the exception of the Mycetophiloidea, which contains five families, the Oligoneura, which contains the Cecidomyiidae, and the families Bibionidae and Scatopsidae, all the families in the Nematocera are aquatic either wholly or in large part. The aquatic species in the Brachycera are contained in five families—Leptidae, Stratiomyiidae, Tabanidae, Empididae, and Dolichopodidae. As already indicated in the foregoing general discussion, the larvae of some of these families are predaceous and may justly be considered beneficial; the others feed upon algae and decaying vegetable matter, and while their presence in water that is intended for drinking purposes is undesirable, it is not necessarily harmful unless the vessel containing them is small and they are numerous enough to foul the water, either with excreta or exuvia. With the exception of some Chironomidae and Culicidae there are few species that frequent reservoirs or cisterns, most of them preferring lakes, ponds, or streams.

My information regarding the habits of the order in general leads me to the conclusion that as a whole their beneficial and injurious activities practically offset each other. The fact that there are injurious species which cause great recognized damage, such as the malarial and other disease-breeding mosquitoes and the Hessian fly, very largely outweighs in the mind of the uninitiated the benefits—few of which are apparent except to a student of the Diptera—that are directly or indirectly due to the presence of other forms. With advance in a knowledge of the biology of the insects of this order will come a realization that their injurious and beneficial effects are practically balanced.

THE EGG LAYING HABITS OF A PARASITIC DIPTERON, *PTERODONTIA*

By J. L. King, University of Illinois

The flies of the genus *Pterodontia* belong to the Dipterous family *Cyrtidae*. This family consists of a small group of strange appearing flies which are characterized by having very small heads composed almost entirely of eyes, a large hump-backed thorax and inflated abdomen. They are of medium or large size, the species described here varying from 4 to 8 mm. in length.

As far as is known, the larvae live as internal parasites in the bodies of spiders and, according to Brauer, while within the abdomen of the host they breathe by placing their posterior spiracles or breathing tube openings into the lung-chambers of the spider, thus taking their air supply from the lungs of the host.

The habits of our North American species are but little known and the writer has been unable to find descriptions of the eggs or egg-laying habits of any of our species. In view of this, the following descriptions of the eggs and egg-laying habits of *Pterodontia flavipes* Gray have been prepared:

On August 7, 1915, the writer, while passing by the border of an open hickory grove, observed several large specimens of *Pterodontia* flying up and down the trunks of some large hickory trees. The flies were observed for about half an hour; during this period they continued to hover up and down the tree trunks from about a foot above the ground to a height of ten to fifteen feet. They flew on the leeward side of the trunks and from one to two inches away from the surface of the bark, and at such times they were so sluggish that it was possible to pick them up in one's fingers, and if allowed to escape they immediately resumed their hovering flight up and down the tree trunk. In fact, they may be pierced through the thorax with a common pin and if released show no particular injury or fright, but continue their hovering flight as before.

Before leaving the locality one of the flies was taken alive and carried in a handkerchief. Upon returning to my field laboratory and transferring the specimen to a bell-jar, it was noted that the handkerchief in which it had been carried was sprinkled with minute black eggs. Further observation of the fly revealed the fact that the eggs were forcibly discharged from the ovipositor in extremely rapid succession, not unlike bullets from a rapid-firing gun. The eggs when first deposited are coated with a sticky substance which causes them to adhere to whatever they hit or fall upon.

The following day some of the trees in the grove were banded with narrow strips of clean white paper. After a brief period several flies appeared hovering over the surface of the bark in the same manner as observed during the previous day. This time, however, with the aid of the white paper strips, their actions were easily interpreted. By watching closely as the flies flew over the paper strips, one could see the eggs appear upon the paper as minute black specks sprinkled in irregular rows. An examination of the bark of these trees showed the leeward side of each tree to be literally sprinkled with hundreds of thousands of eggs.

The eggs contained in the handkerchief numbered 2,300. All of these were deposited by a single female in a period of not over forty-five minutes. Other counts made show that a female fly may deposit as high as 3,977 eggs. The eggs are very minute, measuring 0.18 mm. in length and 0.15 mm. in width. They are slightly compressed and pear-shaped in outline and are of dull black color. Their period of incubation is thirty-two to thirty-three days.*

*For a detailed description of the larvae and other stages see King, J. L., 1916, Observations on the Life History of "Pterodontia flavipes," Gray. Annals Ent. Soc. Amer. Vol. 9, pp. 309-321.

VARIATION IN THE GILLS OF ZYGOPTERA*

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The gills of the nymphs of Zygoptera show features which serve as accurate indices to specific and generic relationships within the suborder. The separation of closely allied species is frequently accomplished with ease by observing the outline of the gill, pigmentation, tracheation and so on. This feature should probably take precedence over the characters of the labium which cease to be of great importance in groups of less than family size.

The groups showing the more marked variations in gill structure are found with the Coenagrionidae, but there are also variations in the gills of Lestinae which serve to distinguish the different species. In the genera of Coenagrionidae the species grouped by means of gill structure conform remarkably to the groups of species, or superspecies, as based on adult characteristics. This feature is evident to a greater degree in Enallagma, and the groups based on both nymphal and adult characters are seen below:

BASED ON ADULT STRUCTURE	BASED ON NYMPHAL GILLS
Enallagma civile. Enallagma carunculatum. Enallagma calverti. Enallagma hageni.	Enallagma civile. Enallagma carunculatum. Enallagma calverti.
	Enallagma hageni.
Enallagma geminatum	Enallagma geminatum
Enallagma exsulans. Enallagma antennatum. Enallagma traviatum.	Enallagma exsulans. Enallagma antennatum. Enallagma traviatum.
Enallagma signatum. Enallagma pollutum.	Enallagma signatum. Enallagma pollutum.

*Based on data now being published in a bulletin of the Illinois State Laboratory of Natural History.

THE PRINCIPLES OF SUBCUTANEOUS MEDICATION BY MEANS OF BACTERIA AND BACTERIAL PRODUCTS

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That there existed small living organisms, too small to be seen by the unaided human eye, has been the thought of scientists since the dawn of history. Several philosophers of old were bold enough to state openly that such organisms existed, and few writers went so far as to frame their speculation on the subject which seemed like anticipations of future discovery. No one ever was able to see these minute organisms until Anton von Leeuwenhoek, the Dutch microscopist, a skilled lens grinder, completed his microscope, and spent several years examining a great variety of natural objects. In the course of his study he chanced to come upon the organisms now known as bacteria—(1683).

Leeuwenhoeck's observations remained isolated and without further improvement until 1786, in which year the Danish zoologist O. F. Muller clearly recognized the difficulty of studying such minute organisms. However, in spite of these obstacles that he encountered Muller succeeded in discovering many structural details of which his predecessors had been ignorant. Indeed, several kind of bacteria were so accurately described by him that they can be identified today as belonging to one or another of the chief group forms.

Another great advance was made by Ehrenberg, 1795 to 1876, who worked upon the animalcules found in infusions of hay and meat. The chief merit of Ehrenberg's work lay in the system that it introduced into the study of micro organisms. Ehrenberg was able to establish a number of different groups among the organisms now called bacteria and recognized fundamental differences between larger forms, such as screw or spiral shapes, rod shaped and spherical and several of the true protozoa with which they had up to this time been classed.

In 1796, Edward Jenner, an English physician and a co-worker with Hunter and Harvey, discovered a new system for the treatment of variola which proved a great success. By taking from an animal infected with variola some blood and injecting it into another animal of the same species, he found that it produced a diseased condition similar to that of the first animal, but in a less virulent form, and that it soon subsided, and that it further protected that animal from subsequent attacks.

On May 4th, 1796, Dr. Jenner injected into the arm of a boy a small quantity of lymph, obtained from a milk maid affected with variola, and found that this produced results similar to those obtained in his animal experiments; the disease was less virulent and the subject soon was protected from it. This was the first injection into man of a substance to protect him against the ravages of disease. Later in the same year he used the lymph of cows and called this liquid vaccine. With this liquid he protected the lives of thousands from the ravages of smallpox.

Van Helmont and Needham, after a number of years of study of these small organisms offered to the world the theory that these forms of life arose by spontaneous generation in such fluids as meat infusions and other organic solutions even after they had been boiled. This was contested by Spallanzani, who showed that when a meat infusion had been boiled three quarters of an hour and kept from contact with the air, the developments of micro organisms would not take place. It was then claimed by the adherents of the theory of spontaneous generation that the expulsion of air by boiling and the arrangements which prevented it from re-entering the vessels also prevented spontaneous generation. Schulze and Schwan then devised methods to permit the entrance of air after it had been heated in a glass tube or passed through sulphuric acid. Schwan also showed that certain poisonous chemicals when added to meat infusions prevented the development of micro organisms, and these chemicals we now call antiseptics. Schroeder allowed air to enter vessels containing boiled organic matters, through glass tubes, which had been plugged with cotton; no growth of organisms resulted. This is the method now used to keep pure cultures of bacteria from becoming contaminated.

Pasteur in 1860 showed that a short boiling of an infusion of organic matter was not sufficient to kill all micro organisms and that some could withstand the temperature of boiling water for several hours. This was substantiated by F. Cohn and Robert Koch, who also showed these resistant forms of micro organisms to be the spores of bacteria. In 1878 Robert Koch completed his brilliant experiments in the making of solid culture media. This enabled the scientific world to recover micro organisms from diseased animals by growing them on this media from the blood or secretions obtained from that animal, and to successfully study their morphology. Koch demonstrated that the changes which took place upon the contact of bacteria and media were those of decomposition, caused by bacteria.

Pasteur, while engaged in research work along the lines of the silkworm disease, and anthrax in cattle for the French government, succeeded in proving that the etiology of these diseases was due to micro organisms. Later he found and reported the cause of chicken cholera, and by inoculation experiments told how to guard against them. Since the fundamental work of Pasteur and Robert Koch, the studies of pathogenic micro organisms in general and of pathogenic bacteria in particular have been placed on a firm basis, and have assumed the greatest importance in the theory and practice of medicine. The connection of bacteria with certain forms of disease was conclusively demonstrated by these men, although it had long been suspected that suppuration was due to the presence of organisms in wounds.

That numerous small organisms scourged and ravaged the human body and that all people did not die during the epidemics of disease proved that the body protected itself against disease; this fact was laid bare to the knowledge of the world by the famous Erlich in his theory of phagocytosis, and side chain theory. He proved that the extensive metabolism of the human body was endowed with the power of eating or feeding upon the micro organisms which invaded the body. This substance which accomplished this was called phagocytes, taken from the Greek, *phagoto,* eat, *cyte,* a cell, are classed to day as leukocytes or white blood corpuscles. They have attractive powers and can remove from the blood the bacteria and foreign bodies of invasions, in the same manner as iron filings are attracted toward a magnet; the iron filings being the disease producing bodies and the magnet, the leukocyte. This is shown by the attraction or repulsion that exists between leukocytes and foreign material in the blood stream, and when this attraction takes place as was demonstrated with the iron filings, it is called a positive chemotaxis. Numerous other observers realized that when an invasion of bacteria into a body had taken place successfully that some of the phagocytic cells had lost their power of eating, and destroying bacterias. This phagocytic power of the body being lessened, the power of the bacteria was increased, and the body was then in a diseased condition. In the accounts of Robert Koch we read that he took pure cultures of living micro organisms, and after introducing them into normal salt solution, killed them with heat, and injected them into a body that was not resistant to the disease produced by the micro organisms used. It was then claimed that after repeated injections, these animals would be inoculated with the disease, due to the fact that phagocytes had been injected by the invasion of dead bacteria.

This led up to the wonderful theory of Metchnikoff, which has continued to the present day. In 1883 Metchnikoff first claimed that phagocytes protected the higher animals against infection by disease producing bacteria, although for years he knew of the presence of phagocytes in lower animals, in the class of "Tunicata" called "Actinia." His experiments on higher animals were quite easy to be carried out.

By defibrinating the blood of a goose, by whipping it with a bundle of pieces of wood or wire he obtained a mixture of blood corpuscles and serum, (the fibrin was removed by the whipping) this defibrinated blood was mixed with physiological salt solution, centrifuged and the clear supernatant fluid pipetted off. In this way he obtained what is now known as "washed red blood corpuscles." A few cubic centimeters of these washed red blood corpuscles were suspended in physiological salt solution and were injected into the peritoneal cavity of a guinea pig, and after a short time removed from the peritoneum together with the exudate from the abdominal cavity with which they had been mixed. He found that the exudate contained numerous large mononuclear white blood corpuscles of the guinea pig, and that these contained many red blood corpuscles of the goose. Then at short intervals of time he removed more exudate for examination and found the goose corpuscles more and more digested in the large mononuclear cells of the guinea pig, demonstrating that certain cells of the Mammalian animals possess phagocytic properties.

Metchnikoff's opponents tried to disprove this by showing that in animals dead from anthrax, numerous anthrax bacilli were seen in the blood, none of which were being or had been taken up or digested by phagocytic cells. Metchnikoff then succeeded in demonstrating that in animals not susceptible to anthrax such phagocytosis of bacilli took place, and that the lack of susceptibility depended upon the fact the anthrax bacilli were taken up and destroyed by the phagocytes. Upon this fact the use of vaccines in medicine is based, the vaccine, being the substance used to increase the phagocytic powers of the body.

Non-susceptibility to a given disease or a given organism or toxin, either under natural conditions or under conditions experimentally produced, is called immunity. Immunity is, in fact, of widely varying degrees and has correspondingly relative significance. So long as an organism continues to exist, it must continue to adapt itself to its invironments, and thus it becomes so modified as to effectually resist influences which, without such modification, would have brought cessation of being. The lower animals are immune to some diseases prevalent in man and certain families have marked resistance to some diseases. These are examples of natural immunity. An individual may be immune by virtue of his being of a certain race or family. Certain animals may possess a congenital natural immunity. For instance, many warm blooded animals, such as guinea pigs, cattle, mice, and rabbits, are susceptible to anthrax, while dogs and rats possess quite a strong, though not an absolute natural immunity against this infection. Man is susceptible to typhoid bacillus and cholera spirillum infections, while all our domestic animals are immune against these so far as natural infection is concerned. Classic is the observation, on the other hand, that one attack of a certain infectious disease affords lifelong immunity against attack of the same disease, while in other diseases the acquired immunity is varying in duration. Persons who have had one attack of measles, scarlatina, typhoid fever, and smallpox are generally immune against a second. The same is true of animals having had hoof and mouth diseases. This is called natural acquired immunity.

We can produce artificial immunity either active or passive. Vaccination or the injection of bacterial toxins, produces active immunity, while the injection of an immunizing serum such as diphtheria antitoxin confers passive immunity. In other words in the first instance the patient supplies his own antibodies—active immunity (in the second instance the anti-bodies are supplied to the patient), passive immunity.

In active immunity, following recovery from either an idiopathic infection or an artificially produced infection, there are developed in the blood the anti-bodies which are inimical to the toxin or the activity of the bacteria of themselves, or which accomplish the destruction of the causative agent by the action of the phagocytes. Normal blood serum has a powerful destructive effect upon many varieties of bacteria, and this power is found to be greatly increased in a patient who has been infected with these bacteria, either naturally or artificially. There can be no doubt that in all cases of acquired immunity, either active or passive, the leucocytes have performed the large and important work of destroying and absorbing the process of phagocytosis.

Pathogenic bacteria secret very powerful soluble toxins which enter the general circulation; whenever such toxins circulate in the blood, there is a tendency to the formation of bodies which neutralize them, and bring about a cure of the conditions, provided that the toxins are not over abundant and have not already done irreparable damage. These bodies which neutralize the soluble toxins are called anti-toxins. The action of the anti-toxin upon a toxin, is best understood by comparison with the well known chemical reaction between acids and alkalies. Just as hydrochloric acid can be neutralized in a test tube with ammonia, so can a soluble toxin be neutralized with its anti-toxins. The principle is the same, although the process is much more complicated in the neutralization of toxin by anti-toxin than of acids by alkalis. The anti-toxin mixture can be injected into a susceptible animal without producing any ill effects. Thus the formation of anti-toxin is another means by which the body protects itself against pathogenic bacteria, and their most important products, toxins.

Wright and Douglas have demonstrated the presence of substances in the blood which act upon bacteria rendering them subject to phagocytes. The best known cause of phagocytosis, and the one occupying the attention of medical men almost exclusively, is the opsonin of the blood serum which was first clearly demonstrated by Wright and Douglas about 1907. Of several protective bodies known to exist in man in normal and immune seria, only the opsonins can be quantitatively determined with any considerable degree of accuracy. It should be remembered, however, that all the immune protective bodies arise from the action of the bacteria, and their chemical products; so that while the opsonins are distinct from others, the probable quantity of the others may be at least inferred from the amount of opsonin found present. Among the anti-bodies found in the serum, we have precipitins which are substances formed by the injection of protein solution and cause sedimentation or precipitation when the serum is mixed with a solution of the same protein as was injected. Agglutinins, which are formed as the result of invasion, or injection of bacteria; and the serum of an individual or animal so treated when brought in contact with the same species of bacteria causes them to collect into clumps; and lysins, the production of which is due within the serum of the recepters, which have the power of combining with the antigen, and also with the complement that exists in the serum of all animals, whether they are infected or not. In determining the amount of opsonin in a given serum, it is necessary to have (1) blood serum from a sick and from a healthy person, (2) leukocytes, (3) a suspension of the organism, the opsonin for which is to be measured.

The leukocytes are prepared by receiving a few drops of the blood in a normal salt solution with one per cent sodium citrate added. The mixture must be shaken and centrifuged at a moderate speed for five minutes. The leukocytes will be found in a grayish layer at the top of the sediment and may be pipetted off.

The blood serum from the person to be tested is obtained by bleeding into glass capsules or tubes and centrifuging.

Bacterial emulsion made from young culture of the required organism is made with 0.85 per cent salt solution: equal parts of the leukocytes, blood serum, and bacterial emulsion are drawn up into a small capillary tube, and mixed in a watch crystal and again drawn into the tube. The tube is then sealed and incubated at blood temperature for about twenty minutes. The mixture is again shaken and smears made and stained with a good blood stain. Many of the bacteria will be found to have been assimilated by the leukocytes. The contents of a fair number, about a hundred, are counted and an average made. Simultaneously with this test, a control is made of a normal individual, one hundred leukocytes are counted and an average taken; the results of the latter divided into the result of the person being tested, give the opsonic index—i.e., if the normal one's average is four bacteria per leukocyte and the tested one is three per leukocyte, we would have three divided by four equals .75; in other words, three-quarters of the quantity of opsonins only are present in the serum of the tested patient.

The opsonic index is increased by the injection of toxins or bacterial bodies into healthy tissues, thereby the phagocytic power of the body is increased in proportion to the increase in opsonic powers.

Vaccines or bacterial vaccines or bacterins as they are now called, serums of anti-toxin, belong to the class of biologic preparations. These do not replace drugs, but are new means in treating diseases caused by bacterial infection, and are given with but one purpose in view, that is to produce immunity whereby the patient may be able to overcome and cease temporarily at least to be susceptible to attacks by pathogenic bacteria.

Bacterines consist of suspensions of killed bacteria. In the preparations of these no animals are needed. The bacteria for a specific bacterine or vaccine are grown on suitable media, removed from this media by washing with normal salt solution, killed by heat and then emulsified in salt solution.

The bacteria are then counted in order that a specified number may be administered at each dose and put up in suitable containers. Bacterines are used to produce active immunity when injected, they stimulate the patient's body cells to produce its own anti-bodies, including such substances as agglutinins, lysins and opsonins. There is no doubt that the efficiency of bacterins depends upon their power to stimulate the formation of opsonins.

The serum or its modified and purified preparation, the globulin solution, is the older and best known of these two classes, i.e., bacterines and serums. The first successful serum, the diphtheria anti-toxin, was discovered by Behring and Kitasato in 1890. Anti-toxins are produced within the body of some animal, the horse being used in most cases. Such an animal is given injection of the toxins, rarely of dead bodies, of a specific disease producing micro-organisms in increasing quantities, until the point of tolerance or maximum resistance has been reached. As a result, anti-toxic substances are produced by these animal cells and they appear in the serum. At the proper time the animal is bled and after various stages of purification and concentration, the blood serum is put up in suitable containers for administration to the human patient.

This serum contains anti-bodies or immune substances which will directly combat the specific infection. By the injection of a serum the physician produces passive immunity. In order that a serum be of greatest therapeutic value it must be of a standard specified strength so that the size of the dose administered may be regulated. This process of regulating serums and bacterines is termed standardization, and in the case of the anti-toxin serum it is done in terms of "anti-toxin units." To test the anti-toxic value guinea pigs of about 250 grams are used. These guinea pigs and the parents of these guinea pigs should never before have been used in the testing of anti-toxin. An anti-toxic unit is to be understood by its effect only.

A unit is capable of neutralizing an amount of toxin, or bacterial poison; that is, in turn, measurable by its fatal effect on guinea pigs in the presence of a standard immunity unit furnished by the United States Government. The immunity unit is mixed with the toxin and administered to guinea pigs. Sufficient toxin must be used to kill the guinea pig notwithstanding the protection afforded by the immunity unit. One anti-toxic unit will just save the life of the guinea pig when injected together with the toxin dose above mentioned.

A short time after an inoculation is made, the opsonic index falls lower than it was previous to the injection of the vaccine. This was named by Wright the negative phase. Shortly after, from a few hours to several days, the opsonic index will rise above the starting point. This is called a positive phase. The amount of opsonins in the blood remains stationary for a variable length of time, and then diminishes. As soon as this diminution is noticed, a second injection of the vaccine should be administered. This second negative phase produced will be less marked than the first, and soon the positive phase comes on, reaching a higher level than that previously. Thus, the injections are repeated from time to time, according to the opsonic index of the patient's blood, and the positive phase attains a higher and higher level until it may be as high or considerably higher than that of a normal person. In other words, if vaccinations are properly given (never during a negative phase,) and as a result the patient's tissues are stimulated in the increased production of opsonins, phagocytosis is increased, and the patient rapidly recovers from his infection because the invading bacteria are disposed of. This is the principle mainly to be remembered for successful application of bacterines or vaccines in infectious diseases caused by pathogenic bacteria.

There are today a great many bacterines manufactured for medical use. Chief among them are the anti-rabic vaccine, the typhoid, pertussis vaccine, meningococcus vaccine, gonococcus vaccine, acne vaccines, anti-streptococcic vaccine, pneumococcus vaccine, staphylococcic vaccine, and a class of important vaccines which come under the head of tuberculins.

Wright carried out very extensive experiments in South America with the pneumonia vaccine. He worked under great difficulties and had great trouble in regulating the sizes and frequency of doses. His main guide in the choice of doses and intervals of administration was the ups and downs of the temperature chart, and clinical symptoms. Of one hundred fifty nine cases given the vaccine treatment fifty died, and of one hundred and forty given the expectant treatment, forty-eight died. In his succeeding experiments, larger doses of vaccine were administered and the percentage of death decreased.

Prophylactic immunization in scarlet fever is still an unsettled point. For some time streptococcus vaccines prepared from cultures isolated from scarlet fever patients have been used in Russia with a moderate amount of success. Later reports show that the results are about uniformly favorable, and the use of this vaccine is free from danger during the last couple of years. Dr. Schultze of New York has obtained very interesting results by using vaccine of a large diplococcus found in connection with scarlet fever.

The use of vaccines in the treatment of chronic diphtheria carriers has been a subject of much research work with a fair amount of success. This work was prompted by the great inconvenience caused to people called diphtheria carriers, who although they showed no signs of illness, were isolated because of the presence of diphtherial bacteria in their throats.

The treatment of pneumonia by vaccines has been successful. In this instance polyvalent vaccines were employed. In 1912, active immunity as well as passive immunity was obtained against the pneumococcus with a soluble vaccine.

Sensitized vaccines have again been brought into the limelight. After many unsuccessful applications of this class of vaccines they were for a time abandoned. In 1914 a sensitized vaccine virus was successfully made, and a case of uterine abscess was successfully treated by this sensitized vaccine of proteus.

An interesting application of vaccine therapy has come up for consideration in the last few years in the Hodgkins disease (pseudoleukemia). The status of the prophylactic vaccination against whooping cough is still an unsettled matter. This is due largely to the fact that small amounts of the vaccine are administered. There is little doubt that the use of vaccines in doses of one hundred million or more will remove all doubt as to its efficiency in controlling epidemics.

The tuberculins, which are divided into a boullion filtrate, concentrated, a dilute, a bazillen emulsion, and ointment for Moro test, tuberculins for von Pirquet test and purified tuberculin discs for ophthalmic tests and tuberculin old are supplied in both the human and bovine types.

Tuberculin old is used chiefly as a diagnostic agent. Tuberculin concentrated is a toxin and produces immunity to the toxin of the bacillus, and not to the bacillus itself. Tuberculin boullion filtrate is used in the treatment of tuberculosis and is administered in doses ranging from 1/100,000 to 1/1000 milligram, the dose is repeated every three to six days.

The use of vaccines is becoming greater and their application wider as time goes on. It is the ultimate hope of physicians to use bacterial products in the fight against Pathogenic Bacteria. One great stumbling block has been the tendency to use small doses; this has been overcome to a great extent. The addition of a vaccine to an infected person by injection throws into the body a great number of poisons. The physician must therefore be very careful in the administration of the initial dose. He must also know whether to administer a serum or a bacterine. A bacterine should be given in cases of localized infection, at the beginning of an acute disease, in chronic infectious diseases and for prophylaxis against typhoid fever and cholera. Serum should be given for immediate prophylaxis against diphtheria, in general infections fully developed, and when on account of the severity of the symptoms, an immediate response is essential.

THE CAUSE OF GASTRIC ULCER*

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A great many theories have been advanced concerning the cause of gastric ulcer. The main feature of most of these theories is that there is a decreased resistance of limited areas of the gastric wall, followed by the digestion of these areas by the unrestricted action of the pepsin. The investigation reported in this paper is concerned with the cause of this diminished resistance. It has been recognized for a long time that the resistance to the action of the digestive juices of limited portions of the mucosa of the stomach is decreased by cutting off the blood supply of these portions as, for example, by a clot

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in a small blood vessel (thrombosis) or by the ligation of the vessel. Under such conditions the area is digested by the pepsin with the formation of an ulcer. The decreased resistance of the areas rendered anemic by cutting off the blood supply has usually been attributed to the deprivation of the areas of nutrition. The frequency of the occurence of gastric ulcer among anemic persons has led many to consider anemia a predisposing factor in the production of ulcer. Lesions produced in the mucosa of normal healthy animals heal, as a rule, with more or less ease. If, however, the animal is rendered anemic by bleeding or by the introduction of some hemolytic agent, thus reducing the oxidative processes, lesions in the gastric mucosa heal very tardily. When the blood supply to a portion of the mucosa is cut off, among other things, the part is deprived of oxygen and for that reason the oxidative processes are decreased.

Araki[1] showed that the oxidative processes are decreased in rabbits rendered anemic by bleeding. In phosphorus poisoning the oxidative processes of the body are decreased[2], and it has been observed that under these conditions the tendency of the tissues to undergo autolysis is increased[3]. In diseases of the circulatory and respiratory systems, where the amount of oxygen is decreased and hence the oxidative processss are decreased, there is a great tendency of all the tissues to undergo self-digestion.[4] These facts would seem to point to some relation between the oxidative processes of the body and the resistance of the tissues to the digestive action of the proteolytic enzymes. Burge[5] showed that pepsin as well as trypsin is easily destroyed by oxidation. Lillie[6] showed that the cells of the gastric mucosa possess intense oxidative properties.

In view of the fact that pepsin is easily destroyed by oxidation, that the cells of the mucosa possess oxidative properties, and that these cells become easily digested when these properties are decreased, the hypothesis is advanced that the mucosa is not digested under normal conditions because the

[1]Araki: Ztschr. f. physiol. Chem., 1894, XIX, 424.

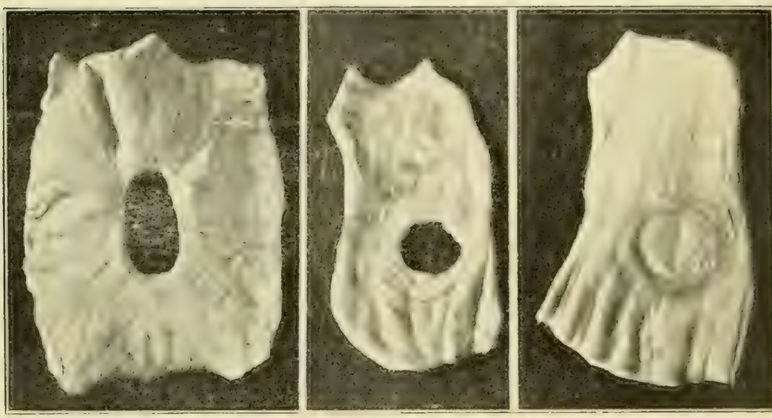
[2]Welsch: Arch. internat. de pharmacod. et de therap., 1905, XIV, 211. Ries: Berl. klin. Wchnschr., 1905, XLII, 44a, 54.

[3]Jacoby: Ztschr. f. physiol. Chem. 1900, XXX, 174.

[4]Schlesinger: Beitr. z. chem. Physiol. u. Path. (Hofmeister's), 1904, IV. 87.

[5]Burge: Am. Jour. Physiol., 1915, XXXVII, 462.

[6]Lillie: Am. Jour. Physiol., 1902, VII. 413.



1 2 3

Fig. 2. Photograph of pieces of gastric mucosa. The central areas of 1 and 2 were exposed to the action of gastric juice, 1 in the presence of atomic oxygyen, 2 in the absence of atomic oxygen. 3. Perforating ulcer of the stomach.

pepsin immediately in contact with the wall of the stomach is rendered inert by the oxidative processes of the cells. This theory assumes that normally a balance exists between the oxidative processes of the cells of the mucosa and the digestive action of the pepsin in the stomach. If this balance is destroyed, as for example by depriving a limited area of oxygen by cutting off the blood supply, thereby decreasing the oxidative processes of the area, this area should be digested by the pepsin with the production of ulcer.

That the mucosa is digested with resulting ulcer under such a condition, has been verified by many observers.

REPORT OF EXPERIMENTS

The following experiments were devised to imitate the protective mechanism as set forth in the foregoing hypothesis:

In Figure 1, (a) is a rubber cuff holding vessels (b) and (c) in position as indicated; (d), a piece of platinum mesh tied over the end of cylinder (b), and (e) a piece of gastric mucosa of the dog tied over the platinum mesh. Before the platinum mesh was tied over the end of the cylinder, platinum black was deposited on it by means of the direct electric current. To 15 c.c. of gastric juice of the dog, 15 c.c. of hydrogen peroxide were added, and the resulting solution was made acid with hydrochloric acid to the same extent as the original gastric juice. This solution was poured into cylinder (b), and the whole preparation placed in a water bath at 38 C. Immediately after the solution was poured into the cylinder an evolution of oxygen gas was observed in the region of the platinum mesh. This, of course, was due to the decomposition of the hydrogen peroxide by the platinum black. Thus the mucosa was exposed to the action of the gastric juice in the presence of atomic oxygen. After six hours, the piece of mucosa was removed from the tube and photographed (Fig. 2A). It may be seen that the central circular area exposed to the action of the gastric juice in the presence of atomic oxygen had not been digested.

Another preparation, similar to the one described, except that no platinum black was deposited on the platinum mesh, was made and placed in the water bath at 38 C. On addition of the gastric juice diluted with hydrogen peroxide no oxygen was given off, there being no platinum black on the mesh; hence this piece of mucosa was exposed to the action of the gastric juice in the absence of atomic oxygen. Figure 2B, is a photograph of the piece of mucosa after the preparation had been in the bath for sixty-five minutes. It may be seen that the central circular area exposed to the action of the gastric juice had been completely digested with the formation of a hole. In Figure 2A the oxidation produced by the atomic oxygen liberated at the surface of the mucosa protected it, while in Figure 2B, no such protection being afforded, the exposed circular area was readily digested with the production of what corresponds to gastric ulcer. Figure 2C is a perforating ulcer of the stomach shown for comparison.

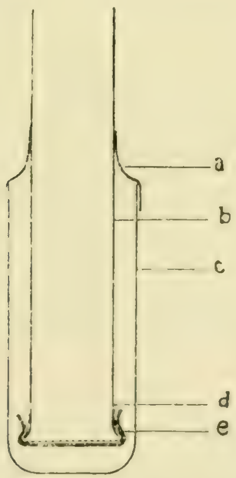
The following experiments were carried out on unicellular organisms to show that when they are introduced into a solution of trypsin they protect themselves from being digested by means of their oxidative processes:

One hundred c.c. of clear pancreatic juice were collected from a cannula in the pancreatic duct of a dog as the result of the repeated injections of secretin into the jugular vein. The trypsinogen in this juice was converted into active trypsin by the addition of 5 c.c. of enterokinase. The resulting trypsin solution was sterilized by exposing it for a few minutes to ultraviolet radiation. It was then placed in a collodion tube and dialyzed against 5 liters of distilled water for twenty-four hours at 10° C. to get rid of most of the dissolved salts.

Five c.c. of the activated dialyzed juice were introduced into each of two long test tubes. Five drops of water containing a great number of living paramecia were introduced into one tube and another five drops of water containing dead parmacia, killed by exposure to ultraviolet radiation, into the other. Both tubes were placed in a water bath at 30° C. At the end of three hours, the paramecia, killed by exposure to ultraviolet radiation before being introduced into the pancreatic juice, were completely digested, while those introduced alive were as active as at the beginning of the experiment. At the end of seventy-two hours, when the experiment was discontinued, these paramecia were still alive and very active.

These two experiments show, as has been recognized for a long time, that living cells are very resistant to the action of proteolytic enzymes, while dead cells are digested with more or less ease.

The digestive strength of the trypsin and the resistance of the living paramecia having been determined by these control experiments, an attempt was made to lower the resistance of the organisms to tryptic activity by decreasing their oxidate processes. Five c.c. of the activated dialyzed pancreatic juice were exposed to the radiation from a quartz mercury-vapor burner for one hour to destroy the trypsin. Living paramecia were introduced into this inactive juice, and hydrogen gas was bubbled through it for ten hours at 30° C. The purpose of bubbling the hydrogen gas through the juice was to deprive the paramecia of most of the oxygen dissolved in the liquid and thus decrease the oxidative processes of the paramecia.



At the end of the ten hours the organisms were alive and active. This experiment shows that the hydrogen gas bubbled through the liquid was not injurious to the paramecia and that there remained in the liquid sufficient oxygen for the life processes of the organisms.

Five drops of water containing paramecia were introduced into 5 c.c. of the activated dialyzed pancreatic juice. Hydrogen gas was bubbled through this liquid as it had been through the inactive juice containing the paramecia. The organisms were observed under the microscope at frequent intervals during the experiment. After about two hours the animals were observed to move less rapidly than at the beginning of the experiment. A little later these slowly moving organisms became more transparent and moved more slowly. As digestion proceeded, the transparency of the paramecia increased, and at the end of the third hour the partially digested organisms appeared as shadows. About half an hour later these paramecia had been completely digested and had gone into solution. These organisms were literally digested while alive and killed by the action of the trypsin itself in the process of digestion.

The preceding experiment was repeated, and when the animals were partially digested, the bubbling of the hydrogen gas through the liquid was discontinued and the bubbling of oxygen gas was substituted. When this was done, the organisms that had not been too much digested were revived, and lived on as normal animals.

These experiments show that the resistance of these unicellular organisms to the digestive action of trypsin is greatly reduced when their oxidative processes are decreased, and that their resistance returns when the oxidative processes are restored. The results obtained on these living unicellular organisms would appear to lend support to the hypothesis advanced in explaining the resistance of the living cells of the gastric mucosa to the digestive action of pepsin.

CONCLUSIONS

The decreased resistance of a circumscribed area of the stomach to the digestive action of gastric juice is due to a decrease in the oxidative processes of the cells of the area. Gastric ulcer is due to the subsequent digestion of the area by pepsin.

The resistance of unicellular organisms (paramecia) to the digestive action of the proteolytic enzymes can be increased or decreased by increasing or decreasing the intensity of the oxidative processes of the organisms, the greater the intensity of the oxidative processes the greater the resistance, and vice versa.

CONSTITUTION AND BY-LAWS*

Illinois Academy of Science

CONSTITUTION

Article I. Name

This Society shall be known as The Illinois Academy of Science.

Article II. Objects

The objects of the Academy shall be the promotion of scientific research, the diffusion of scientific knowledge and scientific spirit, and the unification of the scientific interests of the State.

Article III. Members

The membership of the Academy shall consist of *Active Members, Non-resident Members, and Life Members.*

Active Members shall be persons who are interested in scientific work and are residents of the State of Illinois. Each active member shall pay an initiation fee of one dollar and an annual assessment of one dollar.

Non-resident Members shall be persons who have been members of the Academy but have removed from the State. Their duties and privileges shall be the same as those of active members except that they may not hold office.

Life Members shall be active or non-resident members who have paid fees to the amount of twenty dollars. They shall be free from further annual dues.

For election to any class of membership the candidate's name must be proposed by two members, be approved by a majority of the committee on membership, and receive the assent of three-fourths of the members voting.

All workers in science present at the organization meeting who sign the constitution, upon payment of their initiation fee and their annual dues for 1908, become charter members.

Article IV. Officers

The officers of the Academy shall consist of a President, a Vice-President, a Chairman of each section that may be organized, a Secretary, and a Treasurer. These officers shall be chosen by ballot on recommendation of a nominating committee, at an annual meeting, and shall hold office for one year or until their successors qualify.

They shall perform the duties usually pertaining to their respective offices.

It shall be one of the duties of the President to prepare an address which shall be delivered before the Academy at the annual meeting at which his term of office expires.

The Secretary shall have charge of all the books, collections, and material property belonging to the Academy.

Article V. Council

The Council shall consist of the President, Vice-President, Chairman of each section, Secretary, Treasurer, and the president of the preceding year. To the Council shall be entrusted the management of the affairs of the Academy during the intervals between regular meetings.

Article VI. Standing Committees

The Standing Committees of the Academy shall be a Committee on Publication and a Committee on Membership.

The Committee on Publication shall consist of the President, the Secretary, and a third member chosen annually by the Academy.

The Committee on Membership shall consist of five members chosen annually by the Academy.

Article VII. Meetings

The regular meetings of the Academy shall be held at such time and place as the Council may designate. Special meetings may be called by the Council and shall be called upon written request of twenty members.

Article VIII. Publication

The regular publications of the Academy shall include the transactions of the Academy and such papers as are deemed suitable by the Committee on Publication.

All members shall receive gratis the current issues of the Academy.

Article IX. Affiliation

The Academy may enter into such relations of affiliation with other organizations of appropriate character as may be recommended by the Council and be ordered by a three-fourths vote of the members present at any regular meeting.

Article X. Amendments

This constitution may be amended by a three-fourths vote of the membership present at an annual meeting, provided that notice of the desired change has been sent by the Secretary to all members at last twenty days before such meeting.

BY-LAWS

I. The following shall be the regular order of business:

1. Call to order.
2. Reports of officers.
3. Reports of standing committees.
4. Election of members.
5. Reports of special committees.
6. Appointment of special commitees.
7. Unfinished business.
8. New business.
9. Election of officers.
10. Program.

Adjournment.

II. No meeting of the Academy shall be held without thirty days' previous notice being sent by the Secretary to all members.

III. Fifteen members shall constitute a quorum of the Academy. A majority of the Council shall constitute a quorum of the Council.

IV. No bill against the Academy shall be paid without an order signed by the President and Secretary.

V. Members who shall allow their dues to remain unpaid for three years, having been annually notified of their arrearage by the Treasurer, shall have their names stricken from the roll.

VI. The Secretary shall have charge of the distribution, sale, and exchange of the published transactions of the Academy, under such restrictions as may be imposed by the Council.

VII. The presiding officer shall at each annual meeting appoint a committee of three who shall examine and report in writing upon the account of the Treasurer.

VIII. No paper shall be entitled to a place on the program unless the manuscript or an abstract of the same shall have been previously delivered to the Secretary.

IX. These by-laws may be suspended by a three-fourths vote of the members present at any regular meeting.

List of Members

(Revised August 1917. Not including members elected at the 1917 meeting.)

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