VOL. XX. JANUARY NO. 1

JOURNAL

OF THE

Elisha Mitchell Scientific Society.

ISSUED QUARTERLY

SIGILLUM UNIVERSITAT. CAROL. SEPTENT.

LUX LIBERTAS

Official Publication of the North Carolina
Academy of Science.

CHAPEL HILL, N. C., U. S. A.

TO BE ENTERED AT THE POSTOFFICE AS SECOND CLASS MATTER.

CONTENTS.

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CHAPEL HILL, N. C.:
PUBLISHED BY THE UNIVERSITY OF NORTH CAROLINA
1904

THE UNIVERSITY PRESS
CHAPEL HILL

JOURNAL
OF THE
ELISHA MITCHELL SCIENTIFIC SOCIETY

TWENTIETH YEAR

1904

PROCEEDINGS OF THE NORTH CAROLINA ACADEMY OF SCIENCE.

The first annual meeting of the North Carolina Academy of Science was held at Trinity College, Durham, Nov. 28 and 29, 1902.

A business session was called to order on the morning of the 28th in the physics lecture room. The executive committee made its report and announced the election of twenty-three members.

On motion the executive committee was authorized to publish the proceedings of this meeting, including the constitution and by-laws.

The following amendment to the consritution was proposed, to be acted on at the next annual meeting: To insert after Section 2, Article II.:

"SECTION 3. Any individual who shall contribute one hundred dollars to the maintenance of the Academy may be elected a patron of the Academy."

After the busidess session the presentation of papers was taken up and continued through the afternoon session.

In the evening an address of welcome was delivered by Judge R. W. Winston of Durham; Professor Collier Cobb responding for the Academy. The retiring president, Professor W. L. Poteat, then delivered his address; subject, "*Science and Life*." This was followed by a reception to the members of the Academy by the ladies and faculty of Trinity College.

Another business session was held on the morning of the 29th. On recommendation of the nominating committee, consisting of Professor Collier Cobb, Mr. C. S. Brimley and Professor W. B. Sackett, the following officers were elected:

President, C. W. Edwards.

Vice-President, C E. Brewer.

Secretary-Treasurer, Franklin Sherman, Jr.

Executive Committee, C. W. Edwards and Franklin Sherman, Jr., ex-officio, F. L. Stevens, W. G. Sackett, H. H. Brimley, C. B. Williams, W. L. Poteat, Chas. Baskerville, Collier Cobb.

The following by-law was adopted:

The executive committee shall fill all vacancies occurring between meetings of the Academy.

It was resolved that the Academy extend its heartfelt thanks to the faculty of Trinity College and to the local committee in particular for the kindness shown in arranging so admirably for this meeting.

On the conclusion of business, the presentation of papers was again taken up and continued until the final adjournment at the close of the session.

The program of papers presented at this meeting is as follows:

PAPERS READ.

1. A New Method of Investigating Alternating Current Phenomena. *C. W. Edwards.*
2. Some Recent Work on the Morphology of the Coral Polyps. *J. E. Duerden.*
3. Baccillary Dysentery. *Fred K. Cooke.*
4. Some Interesting Insect Captures. *Franklin Sherman, Jr.*
5. Notes on the Reproduction of Certain Reptiles. *C. S. Brimley.*
6. Ecological Notes on Mosquitoes with Notes on Color Preference. *W. G. Sackett.*

7. Primary Nucleus in Synchytrium. *Mrs. F. L. Steveus.*

8. Changes in the North Carolina Coast During Two Decades, with Notes on the Origin of the Sand-hill Topography of the Coastal Plain. *Collier Cobb.*

9. Predecessors of Roentgen and Becquerel. *Jas. L. Lake.*

10. Distribution of Some Birds in Eastern North Carolina. *T. Gilbert Pearson.*

11. Some Considerations of Rare Earths. *Chas. Baskerville.*

12. Additional North Carolina Desmids (brief). *W. L. Poteat.*

13. Some Plant Formations South-east of Raleigh (brief). *W. G. Sackett.*

14. Notes on North Carolina Plants (brief). *F. L. Stevens.*

The following papers were read by title:

Certain Compounds in the Husk of *Juglans nigra.* *C. E. Brewer.*

Prairies in North Carolina. *W. W. Ashe.*

Diurnal Nutation in *Bidens frondosa.* *F. L. Stevens.*

The Animal Tuberculoses and Their Relation to Human Tuberculoses. *Tait Butler.*

The Pollen of the Gymnosperms. *W. C. Coker.*

List of the Dragon-flies of Raleigh. *C. S. Brimley.*

Notes on Food-habits of Reptiles in Confinement. *C. S. Brimley.*

A Simple Device for Illustrating the Periodic Law to Students. *Chas. Baskerville.*

Improvement in Determination of Halogens in Atomic Weight Work. *Chas. Baskerville.*

Notes on Some North Carolina Algae and Fungi. *W. C. Coker.*

FRANKLIN SHERMAN, JR.,
Secretary.

BUSINESS MEETING.

A business meeting of the North Carolina Academy of Science was held in the office of Tait Butler, State Veterinarian, Raleigh, N. C., on May 1, 1903, at 5:30 P. M., President Edwards in the chair.

Dr. Baskerville reported that the Journal of the Elisha Mitchell Society, published at the State University, might be enlarged to meet the demands of the Academy publications, if the Academy could bear approximately two-thirds of the necessary increase, which was estimated roughly at one hundred dollars.

The following amendments, as recommended by the Executive committee in their meeting at Durham, Feb. 23, 1903, somewhat revised, were adopted:

AMENDMENTS—ARTICLE II.

SECTION 1. Any person actively interested in science, or in the promotion of science, may, upon nomination by two members, be elected a member of the Academy by a majority vote of the executive committee and shall be entitled to all privileges of the Academy.

Relatives of members or others interested in Science may become associates for the annual meeting upon payment of a fee of one dollar. Associates receive the proceedings and are entitled to all privileges of that meeting except voting and holding office.

SEC. 2. The annual dues for members shall be three dollars and for associates one dollar, and any person in arrears at the date of the annual meeting for the presentation of papers forfeits all privileges of the Academy until the dues are paid.

The following by-law was also adopted:

BY-LAW 2.

All elections to membership which take place subsequent to the annual meeting for presentation of paper shall apply to the following calendar year, and no regular dues are to be collected for the year of such election. All elections to membership which take place at or before the annual meeting for the presentation of papers shall apply to the calendar year in which the election takes place, and dues shall be collected accordingly, and dues regularly become payable on January 1 of each year.

The following amendment was proposed, to be acted upon at the next regular meeting:

To amend Article III., Section 1 to read: "and an executive committee of five, etc."

On motion the following committee was appointed to attend to the matter of publication: C. W. Edwards, W. L. Poteat, C. S. Brimley.

On motion the University of North Carolina was selected for the next annual meeting.

The meeting then adjourned.

FRANKLIN SHERMAN, JR.,
Secretary.

SECOND ANNUAL MEETING.

The second annual meeting of the North Carolina Academy of Science was held at the University of North Carolina, Chapel Hill, Nov. 12 and 13, 1903.

The opening session was held in Gerrard Hall on the evening of the 12th. An address of welcome by Dr. F. P. Venable, president of the University, was followed by the annual address of the retiring president, Professor C. W. Edwards, of Trinity College, whose subject was "Science and the State."

On adjournment a smoker was given in the Alumni building to the members of the Academy by the Elisha Mitchell Scientific Society.

On the morning of the 13th a business meeting was held in the Physics lecture room of the Alumni building. In the absence of the secretary, Mr. J. E. Latta, instructor in Physics in the University, was made temporary secretary.

The following amendments to the constitution were adopted:

(1) That the executive committee shall consist of five instead of nine members.

(2) That any individual who shall contribute one hundred dollars to the maintenance of the Academy may be elected a patron of the Academy.

On the recommendation of the nominating committee, consisting of Prof. W. L. Poteat, Prof. Collier Cobb and Mr. C. S. Brimley, the following officers were elected:

President, Chas. Baskerville.

Vice-President, J. I. Hamaker.

Secretary-Treasurer, Franklin Sherman, Jr.

Executive Committee, Chas. Baskerville and Franklin Sherman, Jr., ex-officio, and W. L. Poteat, F. L. Stevens and C. S. Brimley.

Sixteen new members were elected.

The presentation of papers was now taken up for the remainder of the morning session and continued through the afternoon session.

The following papers were presented:

Approaching Sun-Spot Maximum. *Jno. F. Lanneau, Wake Forest.* (Published in full in this Journal).

Notes on Some Pacific Sponges. *H. V. Wilson, Chapel Hill.*

Southeastern Box Tortoises. *C. S. Brimley, Raleigh.* (Abstract).

The six species of Terrapene are enumerated and their alleged characters given with observations on specimens of Terrapene from Raleigh, N. C., several points in Florida, Mimsville, Ga., and Colmesneil, Texas, showing that these characters are frequently not diagnostic. The author is convinced that Terrapene ornata, T. major and T. carolina are distinct species, and he is inclined to believe that T. bauri is at least subspecifically distinct from T. major, and that T. triungis is a southern form of T. carolina and not a distinct species; however he is by no means certain in either case and furthermore he is not even certain that the triungis from Georgia are specifically identical with those from Texas. Number of specimens examined 57 in all.

Terrapene triungis Mimsville, Ga. 20 living; 7 alcoholic;

Bay St. Louis, Miss., 1 alcoholic; Colmesneil, Tex., 3 alcoholic, 1 living, 1 shell; *Terrapene Carolina*, Raleigh, N. C., 7 alcoholic and numerous living examples; *Terrapene Major*, Tallahassee, Fla., 2 alcoholic; Riceboro, Ga., 1 alcoholic; *Terrapene Bauri*, Orlando, Fla., 4 living and 1 alcoholic; Hastings, Fla., 7 alcoholic and 1 live specimen; Mimsville, Ga., 1 alcoholic.

Poisining by Lepiota Morgani pk. *F. L. Stevens, West Raleigh.* Read by W. C. Coker. (Abstract).

Account is given of a personal experience with this fungus, leaving no doubt that on some persons at least it produces an extremely active toxic effect. The article will appear in the Journal of Mycology.

Chapel Hill Liverworts. *W. C. Coker, Chapel Hill.*

This paper appears in full in next issue of this Journal.

Notes on the Transformation of Some Large Moths. *C. S. Brimley, Raleigh.*

A Simple Device for Illustrating the Periodic Law. *Chas. Baskerville, Chapel Hill.* (Will be published in School Science).

Action of Ultra-Violet Light upon Rare Earth Oxides. *Chas. Baskerville.* (American Journal of Science, Dec. 1903.)

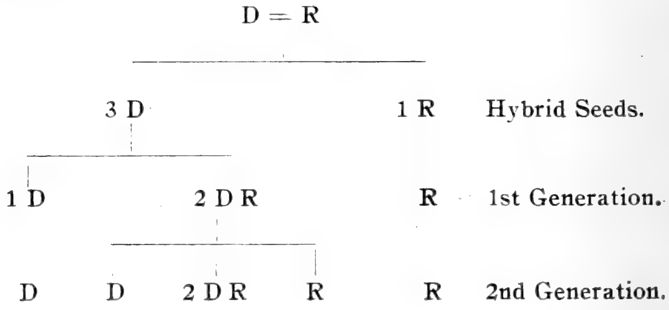
The Effects on Rare Earth Oxides of Radium-barium Compounds, and on the Production of Permanently Luminous Compounds by Mixing the latter with Powdered Minerals. *Chas. Baskerville* and *Geo. F. Kunz.* (Will appear in the Am. J. Sci., Jan. 1904).

Demonstration of the Parasite in Anchylostomiasis (Hookworm Disease). *W. S. Rankin, Wake Forest.*

Mendel's Contribution to a Theory of Heredity. *W. L. Poteat, Wake Forest.* (Abstract).

Gregor Johann Mendel (1822–1884) published in 1866 in an obscure Austrian Journal a paper describing "Experiments in Plant Hybridization." Professor Hugo de Vries, of Amsterdam, who had taken up a similar line of work, brought the paper out of its long hiding in 1900. Its importance was at once apparent. The task which Mendel set himself was, to determine how many forms of offspring hybrids would produce, to arrange these forms according to their separate generations, and to ascertain their statistical relations to each other. He found that the genus *Pisum* fulfilled the conditions essential in the experimental plants. In the work which extended over eight years the pea hybrids were found to be not intermediate between the parental forms as regards the two differentiating characters which were crossed, but one of these characters was transmitted unchanged—the "dominant" character of the pair, and the other seemed hardly to be transmitted at all—the "recessive" character. When a plant having a particular dominant character, as round, smootish seeds, was crossed with one having a corresponding character, namely, angular and deeply wrinkled seeds, the resulting hybrid's seeds were all of them either round and smootish or angular and wrinkled in the proportion of three to one respectively. The next generation from the angular seeds—bred true; from the round seeds (dominant), produced all round seeds, which, however, subsequent generations showed to be of two kinds—pure dominants breeding true, and hybrids (twice as many as the dominants) yielding precisely the same results as were observed in the first generation of the hybrid.

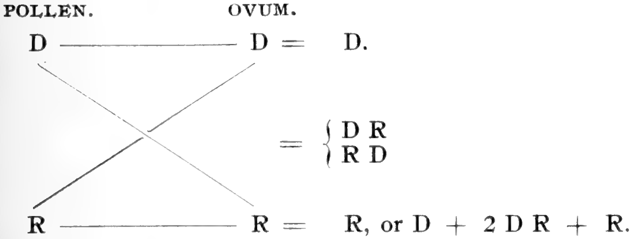
The results may be exhibited graphically in the following scheme, where D stands for a dominant character and R for a recessive :



By substituting values the formula is deduced covering the kinds of hybrid offspring in their numerical relation for a series of generations:

$$D + 2\,D\,R + R.$$

This experimental result accords with what the law of probabilities would lead one to expect in the average of unions of the pollen and egg cells of the two parental forms. On the average D pollen will fertilize equally often D ova and R ova, and R pollen will fertilize equally often D ova and R ova. The chances and the results may be exhibited thus:



Mendel appears to have demonstrated that in the offspring of a hybrid 25 per cent. will show the recessive character and 75 per cent. the dominant, embracing 25 per cent. pure dominants and 50 per cent. hybrids. Accordingly his contribution to a theory of heredity may be stated to be the demonstration of the segregation of characters in the totality of an organism and the individuality of characters, which is preserved down the line of descent.

A New Palaeotrochis Locality, with Some Notes on the Nature of Palaeotrochis. *Collier Cobb, Chapel Hill.* (Illustrated by specimens and microphotographs, with the microscopic sections displayed under a microscope).

An acid volcanic rock full of spherulites closely resembling Palaeotrochis occurs on the elevation three miles west of Chapel Hill known as The Old Volcano. These spherulites are smaller than Palaeotrochis, but they and the rock in which they occur have the same general character as the specimens from the Sam Christian Mine. These from Chapel Hill are smaller and the definite Palaeotrochis form not so abundant among them. Microscopical study shows that they are composed of quartz, fibrous feldspar, and mica (usually green biotite), just the minerals common in the igneous rocks around Chapel Hill. These studies indicate the inorganic origin of Palaeotrochis.

Secondary Radiation from Thorium Compounds. *Geo. B. Pegram, New York.*

The following papers were read by title:

The Flora of the Isle of Palms, South Carolina. *W. C. Coker, Chapel Hill.* (Abstract).

The flora of this island, which is near Charleston, is semitropical in character and presents an interesting transition between that of the Florida and North Carolina coasts. The island is entirely formed of wind-blown sand and its seaward side is furnished with high dunes which offer good advantages for the study of the binding action of grasses and the dune plants.

Twenty-seven species of grasses were found, five of which also occur in the Bahama Islands.

Thirteen species of trees and twenty-five of woody vines occur; the most abundant trees being the Palmetto (Sabal Palmetto), Live Oak (Quercus virens), Laural Oak (Quercus Jaurifolia) and the Old Field Pine (Pinus taeda). Photographs were taken of various plant associations.

Theory of the Induction Coil. *C. W. Edwards, Durham.*

The Granville Tobacco Wilt. *F. L. Stevens and W. G. Sackett, Raleigh.* (Abstract).

A new tobacco disease which is exceedingly destructive is recorded for Granville County. The disease is described, the extent of the damage estimated, and its history and distribution given.

The diseased plants in the effected parts of the root and stem contain numerous bacteria, which probably cause the disease, though definite proof of this point has not yet been had, owing to the absence of tobacco plants in suitable condition for inoculation. The substance of this paper was issued in September as bulletin No. 188 of the North Carolina Experiment Station.

Improvement of Corn by Seed Selection. *C. B. Williams, Raleigh*. (Abstract).

For the improvement of corn there are three methods in general practice: first, by the importation of seed from some reputable grower or breeder; second, by the careful selection of seed corn from one's own field or from a neighbor's; third, by careful selection and growing of seed-corn in a field isolated at least one-quarter of a mile from any other corn field.

The characters that should be taken into account in seed selection are: (1) Selection of ears from stalks that have two or more ears, as it has been demonstrated time and again that two medium sized ears from a stalk give higher yields per acre than one large ear. (2) The stalks should be large at the base and gradually tapering towards the tassel for two reasons: first, because it will be better enabled to withstand drought, and second, because it will stand better in a wind storm. (3) The ears should by all means be of a cylindrical form with both butts and tips filled out, as this is the form that gives the highest percentage yield of shelled corn per ear. The difference in yield, as a result of actual experience of ears of the same length, between those that had the tips filled and those that were not, was something like six bushels per acre. (4) The best shaped kernel is a medium wedge, as this fills the space on the cob most completely. Also the distance between the rows of grains on the cob should be small, while the number of rows should be large, and they should run parallel the full length of the cob, with little or no diminution in size either at the butts or tips.

This paper will appear in full in the Bulletin of the North Carolina Department of Agriculture, Vol. 24, No. 9.

The Forms of Sand-Dunes as Influenced by Neighboring Forests. *Collier Cobb, Chapel Hill.* (Illustrated by photographs).

While the deforesting of the sandreefs is the primary cause of the dunes along the North Carolina coast, there are several instances in which the trees are the obstacles which have produced the dunes. In all these cases "The Banks" run directly across the course of the prevailing winds, which come from the southwest, and just as soon as the vegetation becomes so dense that it prevents this southwest wind from blowing the wave-driven sand back into the sea, a sandwave forms equal in height to the height of the forest. This is best shown in the high dune north of Manteo, on Roanoke Island. It is also noticeable on Currituck Beach, and at several points opposite Masonboro Sound; and forests were influential in forming the dunes at Nag's Head. On the Kinnakeet section of Hatteras Island the dunes were started by the deforesting of a strip next the shore, when they rose to the height of the forest which they finally covered and destroyed. The barren sandwaste there is still known as "The Great Woods." Dunes in many of these cases along our coast might be removed by thinning out the forest and removing the tangle of vines and undergrowth which prevent the west winds from driving the sands back into the sea.

Even where the dunes are formed by the prevailing winds, as between Fort Caswell and Lockwood's Folly and on Shackleford Banks, in every case where the forest growth is dense the encroaching bank of moving sand is at the same height as the tops of the trees. When the trees are sparse and scattered in clumps the moving sands form irregular sandhills instead of great waves.

Work on a List of Insects of North Carolina. *Franklin Sherman, Jr., Raleigh.* (Abstract).

The author is endeavoring to compile a card-catalogue of all species of insects actually known to occur within the State of North Carolina. Three methods are being followed: (1)

securing accurate identification of specimens now being collected; (2) compiling lists of all species from North Carolina found in the larger collections of the country; (3) making lists from all authoritative published literature. The work has only been in progress about one year, and only certain groups have yet been catalogued at all.

Under the first head chief attention has been given to the State collections at Raleigh in charge of the author, and the private collections of Mr. C. S. Brimley at Raleigh, these being the only ones of any extent known to be in the state. Mr. Brimley's work has largely contributed to make the catalogue as complete as it now is. The work of compiling lists from the collections of the country and from the published literature is under way, though being carried on at considerable disadvantage,

Life Histories of Some Southern Birds. *T. G. Pearson, Greensboro.*

List of the Cicindelldae of North Carolina with Notes on the Species. *Franklin Sherman, Jr.* (Abstract).

During the years 1901 and 1902 the author devoted considerable attention to collecting the Tiger beetles of the State. The species where not known positively by the author were identified by competent persons. The list, including species recorded by others as well as those collected by the author, contains nineteen distinct species and three varieties. Of these all save one species and one variety are represented in the collection of the N. C. Department of Agriculture.

The list contains the following:

1 Tetvacha carolina, Linn.
2 " virginica, Linn.
3 Cicindela unipunctata, Fab.
4 " scuttellaris *var.* unicolor, Dej.
4a " " *var.* modesta, Dej.
4b " scuttellaris *var.* rugifrons, Dej.
5 " 6-guttata, Fab.
5a " " *var.* Harrissi, Leng.
6 " patruela, Dej.

7 Cicindela purpurea, Oliv.
8 “ splendida, Hentz.
9 “ vulgaris, Say.
10 “ reponda, Dej.
11 “ 12-guttata, Dej.
12 “ hirlicollis, Say.
13 “ punctulata, Fab.
14 “ dorsalis *var.* media, Lec.
15 “ marginata, Fab.
16 “ blandada, Lec.
17 “ gratiosa, Guer.
18 “ rufiventris, Dej.
19 “ abdominalis, Fab.

To be published in full in “Entomological New[illegible]”

Observations on the Cytology of the Phycomcetes. *Adeline C. Stephens, West Raleigh.*

Rare North Carolina Birds. *T. G. Pearson, Greensboro.*

After the presentation of papers the following resolution was adopted: “That the North Carolina Academy of Science hereby expresses its heartfelt appreciation of the many courtesies extended to it by the President and faculty of the University, both collectively and individually.”

The Academy then adjourned.

At 8 o'clock in the evening a public lecture, complimentary to the Academy, was given by Dr. Baskerville, President of the Elisha Mitchell Scientific Society, in Gerrard Hall. Subject: “Fluorescence, Phosphorescence, Action of Ultra-violet Light, Roentgen Rays, and Radium upon Minerals and Gems.” (Illustrated by experiments and stereopticon.)

This was followed by a reception to the members of the Academy by the ladies and faculty of the University in the Zeta Psi Fraternity Hall.

J. E. LATTA,
Temporary Secretary.

CONSTITUTION.

ARTICLE I.

NAME AND OBJECT.

SECTION 1. The name of this organization shall be the "NORTH CAROLINA ACADEMY OF SCIENCE."

SEC. 2. The objects of the Academy shall be to promote study and scientific research and to furnish, so far as practicable, a means of publication of such articles as may be deemed worthy.

ARTICLE II.

MEMBERSHIP AND DUES.

SECTION 1. Any person actively interested in science, or the promotion of science, may, upon nomination by two members, be elected a Member of the Academy by a majority vote of the Executive Committee, and shall be entitled to all privileges of the Academy.

Relatives of members, or others interested in science, may become Associates for the annual meeting, upon the payment of a fee of one dollar. Associates receive the proceedings, and are entitled to all privileges of that meeting except voting and holding office.

SEC. 2. The annual dues for members shall be three dollars, and for Associates one dollar, and any person in arrears at the date of the annual meeting for presentation of papers, forfeits all privileges of the Academy until the dues are paid.

ARTICLE III.

OFFICERS.

SECTION 1. The officers of the Academy shall be a President, Vice-President, Secretary-Treasurer, and an Executive Committee of five, including the President and Secretary, of which three shall constitute a quorum. All officers shall be elected annually, by ballot, by majority vote.

SEC. 2. The duties of all officers shall be such as usually pertain to such positions.

ARTICLE IV.

MEETINGS.

SECTION 1. The time and place of all meetings shall be determined by the Executive Committee, but there shall be at least one meeting annually for the presentation and discussion of papers, and at least one business meeting annually.

SEC. 2. Two weeks' notice shall be given of all meetings and those present shall constitute a quorum.

ARTICLE V.

PUBLICATIONS.

SECTION 1. The official organ of the Academy shall be known as the "*Journal of the North Carolina Academy of Science*," over which the Executive Committee shall have general control, but the detail work shall be left to an Editorial Committee of three, whom the Executive Committee shall elect.

ARTICLE VI.

AMENDMENTS.

SECTION 1. This Constitution may be amended by a two-thirds vote of those present at any regular meeting; *Provided*, That such amendments be submitted in writing to the Executive Committee at least two weeks before the meeting at which action is to be taken.

BY-LAWS.

1. The Executive Committee shall fill all vacancies occurring between meetings of the Academy.

2. All elections to membership, which take place subse-

quent to the annual meeting for presentation of papers, shall apply to the following calendar year, and no regular dues can be collected for the year of such election. All elections to membership, which take place at or before the annual meeting for the presentation of papers, shall apply to the calendar year in which the election takes place, and dues shall be collected accordingly; and dues regularly become payable on January 1st of each year.

RESOLUTION OF EXECUTIVE COMMITTEE.

Resolved, That upon the written request of three or more members, the Secretary shall call a meeting of the Committee to consider such matters as may be laid before it, said meeting to take place within ten days from the time the reqeust is submitted.

LIST OF MEMBERS.

Andrews, W. J.,	Raleigh.
Ashe, W. W.,	"
Baskerville, Chas., Univ. N. C.,	Chapel Hill.
Battle, K. P.,	Raleigh.
Beardslee, Henry C.,	Asheville.
Binford, Raymond, Guilford College,	Guilford College.
Brewer, C. E., Wake Forest College,	Wake Forest.
Brinkley, C. S.,	Raleigh.
Burkett, Chas. W. A. & M. College.	West Raleigh.
Butler, Tait, Dept. Agr.,	Raleigh.
Cain, W. M., University N. C.,	Chapel Hill.
Chaplin. Spencer,	Littleton.
Cobb, Collier,	Chapel Hill.
Coker, R. E., Biological Laboratory.,	Beaufort.
Coker, W. C., University N. C.,	Chapel Hill.
Cooke, Fred K., Wake Forest College,	Wake Forest.
Duerden, J. E., University N. C.,	Chapel Hill.
Edwards, C. W., Trinity College,	Durham.
Garrett, Mrs. R. U.,	Asheville.

Gore, J. W., University N. C.,	Chapel Hill.
Hammaker, J. T., Trinity College.,	Durham.
Haskell, A. A., A. & M. College,	West Raleigh.
Henderson, A., University N. C.,	Chapel Hill.
Hoffman, S. W.,	Statesville.
Holmes, Jos. A., Geological Survey,	Chapel Hill.
Howell, E. V., University N. C.,	" "
*Kesler, J. L.,	Raleigh.
Kilgore, B. W. Dept. Agr.,	"
Lake, Jas. L., Wake Forest College,	Wake Forest.
Lanneau, M. A., Wake Forest College,	" "
Latta, J. E., University N. C.	Chapel Hill.
Lewis, R. H., State Board Health,	Raleigh.
Massey, W. F.,	"
*Meade, Miss A. M.,	"
Morrison, W. G., A. & M. College,	West Raleigh.
Myers, E. W.,	Greensboro.
Pearson, T. Gilbert, Normal College,	"
Pegram, W. H., Trinity College,	Durham.
Poteat, W. L., Wake Forest College,	Wake Forest.
Rankin, W. S., " " "	" "
Roberts, G. A., Dept. Agr.	Raleigh
*Royster. H. A.,	"
Sackett, W. G., Baptist Female University,	"
Shermau, Franklin, Jr., Dept. Agr.,	"
Smith, Henry L., Davidson College,	Davidson.

* Moved to another State.

APPROACHING SUNSPOT MAXIMUM.

J. F. LANNEAU.

The condition of the sun's surface as to spots—when most pronounced, most persistent—is clearly a matter of judgment, and therefore must lack precision as to date.

The last maximum occurred in or near the year 1893. Thereafter, for six or seven years the spots diminished in size and number. During the past three years it has been a very rare occurrence to see on the sun even a small spot. But beginning last July, there is now a decided renewal of solar disturbance.

My observations at Wake Forest are made with a five inch equatorial. It has a clock work motor, and also two adjusting rods at the eye end for movements in declination and right ascension.

A polarizing eye-piece is so used as to show the sun's disk reversed east and west, but normal north and south.

In default of a micrometer attachment for exact determination of size and location of spots, approximate measurements are made by stopping the clock work, and then noting intervals between transit of spot and transits of sun's east and west limb. Obviously, the distances are proportional to the intervals of time.

Measurements are also made without stopping the clockwork, by using each adjusting rod as a micrometer screw. To so use them, I first find by careful repetition the number of turns or partial turns of the declination rod to move the horizontal wire of the eye-piece north and south the full breadth of the sun's disk; and in like manner, the number of turns of the other rod to move the vertical wire east and west across the disk.

Then, using the rods in turn, relative distances at right angles are found. Points are thus located, and lengths determined.

Observations of the sun during July and for the past thirty days supply the material for this paper.

At noon of July 1st there was a single small spot on the sun's disk. On the 9th there were 53—forming three groups. Their relative positions, and that of others observed during the month, are shown in the sixteen drawings which illustrated "Sunspots in July," published in Popular Astronomy for August.

By the courtesy of the publishers the drawings are here reproduced; also a part of the matter of this paper. Fig. 1 represents the sun's disk at noon July 9th. Group 1, on the left, is simply indicated by three spots—the largest of its 21 spots. Group 2, of 17 spots, and group 3, on the right, of 15 spots, are indicated each by its two chief spots.

By the next noon a half dozen spots had disappeared, or had emerged with others. At noon July 11th several spots in group 3 were much enlarged, as shown in the drawing for that day. But of the 53 spots in view two days before, only 34 remained.

By July 14th group 1 had passed out of view beyond the sun's western edge; and of groups 2 and 3 there remained only 4 spots. By the next noon, July 15, all had passed beyond view except a single spot north of the equator. But a new group of 8 spots had appeared on the disk's south-east quarter (Fig. 5.)

This group, it is interesting to note, had evidently formed since noon of the previous day—for then that part of the sun's disk was without blemish.

So too, before the next noon another new group formed in the north-east quarter—group 5, shown in drawing for the 16th. And again, on the 24th, there appeared a newly formed group of 11 spots. It was still conspicuous on the 29th, the last day of my July observations.

Within that month as many as 90 spots marred the solar surface—part of them north of the sun's equator and part south, in two fairly well defined belts or zones as shown in the drawings.

N

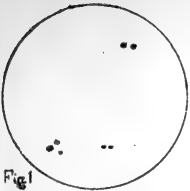


Fig 1

July 9, 1903 Noon

Seven large spots.

Group 1, in S-W qr. 21 spots
" 2. " S-E " 17 "
" 3. " N-E " 15 "
(Small spots not shown)

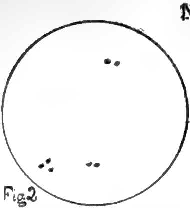


Fig 2

July 10 Noon

Large spots little changed.

In group 1, only 11 spots seen
" " 2 21 " "
" " 3 15 " "

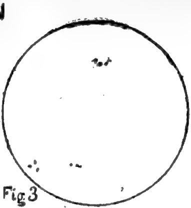


Fig 3

July 11 Noon

More large spots

In group 1, only 5 spots seen
" " 2 14 " "
" " 3 15 " "

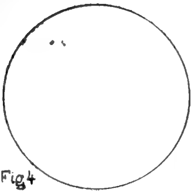


Fig 4

July 14 Noon

Only four large spots

Group 1, gone - passed w-limb
" 2 only one spot seen
" 3 three spots

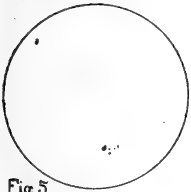


Fig 5

July 15 Noon

Group 1, gone - passed w-limb
" 2
" 3, only one spot seen
" 4, a new group, of at least eight spots - in S-E qr

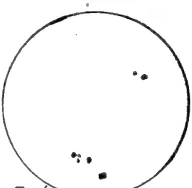


Fig 6

July 16 Noon

Group 3, one spot quite narrow
" 4, only five spots seen
" 5, a new group of two spots - in the N-E quarter

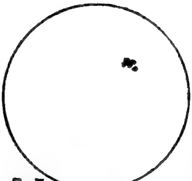


Fig 7

July 17 Noon

Cloud-veils hinder seeing

Only group 5 visible - and shows three additional spots

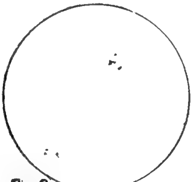


Fig 8

July 18 Noon

Group 4 much changed

Group 5 shows a new spot to the north

W

E

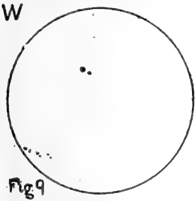


Fig 9

July 20 Noon

Group 4, six small spots
5, only two "

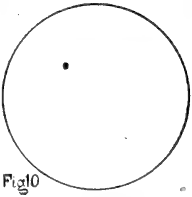


Fig 10

July 21 Noon

Group 4, not visible.
" 5 only one spot

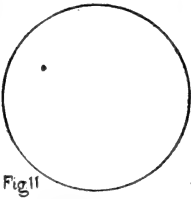


Fig 11

July 22 Noon

Group 5 shows a single spot

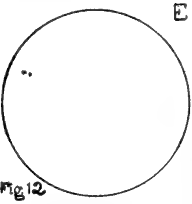


Fig 12

July 23 Noon

Group 5 shows two distinct spots

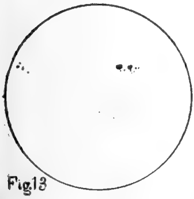


Fig 13

July 24 Noon

Group 5 shows five spots.
" 6 is a new group of two large and at least nine small spots - formed since the preceding noon

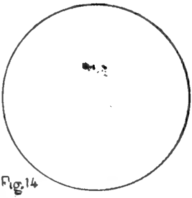


Fig. 14

July 25 Noon

Only group 6 shows - one large spot with double nucleus, seven medium spots, and seven small ones

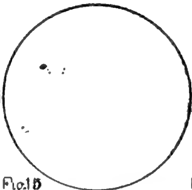


Fig 15

July 27 Noon

Group 6 shows fewer spots
" 7 is a new group of two spots, in the S-W quarter, but nearer the equator than were groups 1, 2 & 4

Fig 16

July 29 Noon

Only group 6 in view - much changed

S

No such persistence and rapid succession of spots and groups has occurred in the past five or six years. They were certainly heralds of an approaching sunspot maximum.

These numerous July sunspots were indeed all relatively quite small. And size as well as number is an element in such a maximum. This element of size, however, has already begun to appear.

In October a very large group of spots darkened the sun's disk. By using a shield of smoked glass, it could be seen with the naked eye. My first observation of it was made at noon on the 14th. It was then larger than any group seen since the 13th of February, 1892.

By October 18th it reached the sun's western limb and passed out of view. But in due time—at its earth-rise—it reappeared to us on the sun's eastern edge. It was there in full view when I looked in the morning of October 30th.

It had greatly altered in form. Earlier in the month it was somewhat rectangular in shape. Its vast area excited general interest. As estimated by good authorities it was 120,000 miles long and 40,000 miles broad. That is, it covered an area more than 24 times the entire surface of our earth.

When again seen at Wake Forest, October 30th, just after its reappearance, it had divided into three great spots. Four days later, when well advanced into view, it was more changed—one spot had almost closed; each of the other two had expanded and about them were grouped 18 relatively small spots. With like mutations it remained a conspicuous object until yesterday, November 12th, when it again passed the sun's western edge out of view.

Meanwhile, two other extensive groups appeared. The first of these was observed October 26th, just as it rounded the sun's eastern edge.

It was triangular in shape and about one third the size of the great group which has now twice passed the western edge. My notes record its varied aspects from day to day until it too passed the sun's western edge on the 7th of November.

The other group—the third in order of these extensive disturbances—was seen near the east limb Nov. 4th. Next day, when more fully in view, it showed four very large spots with 15 smaller ones clustered about them. Its area exceeded that of its immediate predecessor and its changes in form were more surprising.

These three great groups, in view during the past thirty days, had a total area more than 40 times the surface of our earth.

They amply furnish the element of size, as the July sunspots gave that of number.

Number and size of spots indicate growing solar disturbance, and evidence unmistakably an approaching sunspot maximum

The period from one maximum to the next being about 11 years, we may expect the one now approaching to culminate in or near the year 1904—next year.

It is not intended in this brief paper to discuss the many-sided subject of sunspots; still less to even question profundities of the sun's constitution, or to consider the sources of its seemingly exhaustless energy.

I add, however, a single suggestion as to the nature of sunspots.

They are often referred to as furious solar storms or cyclones. Unquestionably, in spot areas the surface material is tossed and torn asunder and adjacent glistening faculæ consist of solar matter thrown into wildly irregular ranges piled many times mountain high.

But *can* there be at the sun's fiercely hot surface any such *difference* of temperature as is essential to movements in anywise analogous to storms terestrial?

Moreover we note on the sun a fairly sharp boundary between the dark disturbed areas and the adjoining bright regions; while here, on the earth, there is a gradual transition from regions of storm to regions of calm.

Again, storms sweep the earth's surface; but visible motion, in sunspots, or appearance of motion is mainly vertical.

In either view allowing remoteness of resemblance, may we not liken sunspots to our earthquakes rather than to our wind storms?

Is it objected that a sunspot covers a great area, and often persists for weeks or months?

True our earthquakes usually produce *visible* results only in small areas, and quickly subside; but often they are *felt* throughout an extensive territory.

The earthquake of last week, Nov. 4th, which caused consternation in the city of St. Louis, was felt in eight states—Missouri, Illinois, Indiana, Kentucky, Tennessee, Mississippi, Louisiana and Arkansas.

In the year 357 A. D. an earthquake in that ill-fated region which we now know as politically convulsed Macedonia, was so wide spread that it swallowed up 150 cities.

The great earthquake of 1755 which destroyed Lisbon with its 50,000 people, destroyed or damaged several other cities in Portugal and some in Spain and in Morocco and extended its disasters east to Arabia and west to the island of Madeira.

In 394 A. D. an earthquake in Europe wrought its destruction of city after city for fully one month; and one in Constantinople in the year 480 A. D. convulsed that region for forty days.

In point of fact, then, as regards both extent and duration there *is* analogy between the sunspots and the earthquake.

From these several considerations—somewhat uniform surface temperature, sharp demarcation, preponderance of vertical motion, and analogy in extent and duration—we may say the spots are in no sense solar surface storms, but rather deep seated *sunquakes*.

As shown, the first great sunquake in October was of vast extent, and displayed its vigor for more than a month.

The sunspot maximum at hand—*sunquake* maximum—promises abundant opportunity for noting other such outbursts of solar energy—some perhaps on a still grander scale.

THE BOX TORTOISES OF SOUTHEASTERN NORTH AMERICA.

C. S. BRIMLEY.

The Box Tortoises (genus Terrapene Merrem 1820=Cistudo Auctorum) comprise a group of six closely related forms, of which one is known only from Mexico, while the other five are found in the United States.

The described forms are:

1. Terrapene carolina (L), 1758.
2. Terrapene triungis (Ag), 1857.
3. Terrapene mexicana (Gray), 1849.
4. Terrapene ornata (Ag), 1857.
5. Terrapene major (Ag), 1857.
6. Terrapene bauri (Taylor), 1895.

The* characters of these species as given by W. E. Taylor are as follows:

I. Three digits on the hind foot.

1. Zygomatic arch complete. Webs absent. Phalanges on the fore foot, 2, 3, 3, 3, 2; hind foot, 2, 3, 3, 2, 1. *Bauri.*

2. Zygomatic arch incomplete. Webs absent. (a) Number of phalanges in the fore foot, 2, 3, 3, 2, 2; hind foot, 2, 3, 3, 2, 1. Carapace tectiform *Mexicana.* (b) Number of phalanges in the fore foot, 2, 3, 3, 2, 2; hind foot, 2, 3, 3, 2, 1. Carapace not tectiform *Triungis.*

II. Four digits on the hind foot.

1. Zygomatic arch complete. Webs distinct. Phalanges in the fore foot, 2, 3, 2, 3, 2; hind foot, 2, 3, 3, 3, 1. *Major.*

2. Zygomatic arch rudimentary. Digits slightly webbed. Phalanges in the fore foot, 2, 3, 3, 3, 2; hind foot, 2, 3, 3, 3, 2. Carapace keeled. *Carolina.*

3. Zygomatic arch absent. Phalanges in the fore foot,

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*The Box Tortoises of North America by W. E. Taylor, Proc. U. S. N. M., Vol. XVII., pp. 573–588. 1895.

2, 2, 2, 2, 2; hind foot, 2, 3, 3, 3, 1. Carapace not keeled. *Ornata.*

The same year *Cope, relying on the same characters, divided Terrapene into four genera, viz.:

1. *Terrapene* Merrem, with four digits in the hind foot and zygomatic arch incomplete (T. carolina and T. ornata).

2. *Onychotrea* Gray. Three digits in the hind foot and zygomatic arch incomplete (T. mexicana and T. triungis).

3. *Pariemys* Cope. Three digits in the hind foot, zygomatic arch incomplete (T. bauri).

4. *Toxaspis* Cope. Four digits in the hind foot, zygomatic arch complete (T. major).

Both Cope and Taylor use the word "digit" in these tables in a misleading manner. What is really meant is "claw" or "clawed digit"; all the species of Terrrpene having at least four digits from an osteological point of view, the fourth digit not being distinguishable in the flesh except when terminating in a claw. Taylor's diagnosis of the species would be satisfactory enough were it not for the fact that some of the characters relied upon are subject to variation in the same species.

Having been considerably puzzled by this individual variation in my endeavor to satisfactorily identify specimens of these forms, I have taken pains during the past two or three years to examine specimens of the various forms which have passed through my hands in order to ascertain so far as possible with the material at my disposal their relation to one another.

So far I have come to the conclusion that of the five forms inhabiting the United States, three are undoubtedly good species, viz., *carolina*, *major* and *ornata*. With regard to the othertwo *bauri* may be identical with *major*, or it may be the Florida local race of that species, or it may be extinct; I cannot tell which. Western *triungis* I believe to be at least a

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*Taylor on Box Tortoises, by E. D. Cope, Am. Naturalist, 1895, August; pp. 756-7.

well marked race of *carolina* and not unlikely a distinct species. *Triunguis* from Georgia may be intergrades between typical *triunguis* and *carolina*, or they may be possibly in part hybrids with *bauri*. I will now discuss the specimens I have examined in detail.

Terrapene carolina. Specimens from Raleigh show the following characteristics: carapace marked with large yellow spots, these often forming to some extent partially concentric figures; keel of the carapace always present, but not marked by a continuous yellow line. Plastron usually black in adults, often showing light spaces, apparently due to abrasion; in younger specimens it is usually yellow more or less marked with dusky, head usually with yellow spots. Hind feet usually larger and stronger than in *triungis*, usually with four claws, but I have seen three specimens with three-clawed hind feet from this locality. Zygomatic arch incomplete, but the quadratojugal very variable in size and shape; in five specimens examined Feb. 11, 1903, two had the quadratojugal long nearly extending to the jugal, nearly completing the arch; in two it was small and triangular, and in the fifth absent altogther.

The newly hatched young of this species have the carapace broad with the keel marked by a row of yellow spots, the head is without yellow markings in the very young, though usually marked with yellow spots in the adult.

Terrapene triungis. Five specimen of *triungis* fromColmesneil in Eastern Texas show the following characteristics: the carapace is shorter and rounder than in any other species examined, the ground color is light brown in all, but the markings show an interesting variation—a living specimen received Oct. 22, 1902, had the carapace marked with a few radiating black lines only, no yellow spots; a shell of one of the others shows very numerous rather faint yellow spots arranged in radiating lines, the upper edges of the lateral plates with some black markings and a few black spots interspersed with the yellow spots; a third specimen has very numerous distinct yellow spots arranged in radiating lines; a fourth has a little black only, with faint indications of yellow spots; a fifth is practically unmarked. All these five have the plastron light brown unmarked and three claws on the hind feet; the edge of the hind foot beyond the third claw is straight in all five withont a notch showing the termination of the fourth digit. Feet unwebbed in all five. One of the five has only traces of a keel.

These were examined with regard to the quadratojugal. In one of these it was absent; in the other two, small and triangular.

Terrapene triungis (?) from Georgia. These are a very variable lot and I am doubtful whether they are the same species as those from Colmesneil, Texas. These Georgia specimens appear to me to be probably a three-clawed form of *T. carolina* but present some differences.

In twenty living specimens examined in May and June, 1903, five had the hind feet four-clawed and fifteen had them three-clawed. Nearly all the latter had a notch on the hind foot showing the termination of the fourth digit. This notch was absent in one specimen and only slightly indicated in several others. The markings on plastron and carapace are quite variable. The former is usually more or less variegated, the markings frequently assuming the regular pattern which is characteristic of *T. carolina*. Often, however, they are irregular and the plastron is frequently all yellow, but in one specimen only have I seen it all dark.

The carapace is dark brown usually marked with roundish yellow spots which vary greatly in size, but are never as small or numerous as in the Colmesneil specimens. These spots sometimes largely coalesce forming irregular yellow markings which may occupy the greater port of the shell to the exclusion of the ground color.

The head is usually marked with large round yellow spots, sometimes, hewever, these are small or mainly absent and sometimes the head markings are similar to those of T. *bauri*.

The specimens I have seen average smaller than Raleigh specimens of T. *carolina* and the carapace is usually smoother and less flaring behind.

The zygomatic arch is incomplete in all specimens examined, but the quadratojugal is variable, in six specimens examined it is absent in three, small and triangular in one and in two others long and slender nearly completing the zygomatic arch; one of these last two has the head and shell markings nearly as in *bauri*, the other is an average *triungis.*

Hind feet narrower than in *carolina* usually not at all webbed. A small specimen from Hancock Co., Miss., has the hind feet unwebbed with three claws and notch; quadratojugal small triangular; markings much as in the average of Georgia specimens.

Two specimens just hatched, from Mimsville, Ga., are indistinguishable from *carolina* of the same age from Raleigh.

Terrapene bauri. This species was originally described in 1895 by Taylor from a single three-clawed specimen with zygmatic arch present and may be identical with *major* or a local race of that species, however, as Florida specimens seem tolerably constant in characters and as the few specimens of undoubted *major* that I have seen, do not agree exactly with them, I think it best to treat it provisionally as distinct. Nearly all Florida specimens I have seen have constant head markings. These are a yellow line from lower edge of orbit crossing the corner of the mouth, a yellow line from posterior corner of orbit backward down neck, a yellow line commencing just behind nostril and proceeding just above orbits, ending just behind orbits, a yellow line down neck in line with foregoing.

The carapace is usually darker brown than in the other species, marked with narrow yellow radiating lines; sometimes these lines are broken into spots and sometimes the spots are irregular and not in rows. This latter variation seems to be due in some specimens to the animal having been "burnt over" and the shell scarred, in which case the pattern on the renewed dermal plates seems to be always irregular. Keel always present, marked by a continuous yellow stripe. Plastron usually yellow, unmarked, sometimes variegated with brown. Hind feet usually slightly webbed but the amount of webbing very variable, some specimens with feet unwebbed, others with the webs comparatively well developed.

Hind claws three or four; of the earlier specimens received from Florida nearly all were three-clawed, in those received lately four-clawed hind feet seem to be more usual. Of four typically marked *bauri* received November 12, 1903 from Orlando, Fla., one has the hind claws four on both feet, two have them three on both feet, and one has four on one foot and three on the other, zygomatic arch complete in every specimen I have ever examined from Florida. Dr. Lonnberg* however states that the skull of a specimen from Orange Co., Fla., in his possession, had no zygomatic arch, not even the slightest rudiment of a quadrato jugal being present.

The carapace of T. *bauri*, I might add is narrower in proportion than that of the other forms and has a less tendency to flare outward behind.

Young T. *bauri* just hatched show the characteristic head markings, narrower carapace, and yellow stripe down the keel of the adult.

Terrapene major, Two specimens from Tallahassee in continental Florida are the largest Terrapene I have ever had, measuring 170 and 180 mm in lengh of shell. The shell is not as narrow and flares outwardly more behind than in *bauri*, the carapace is dark brown with yellow spots arranged radially and a yellow stripe down the keel. Head with yellow markings, but not as in *bauri*. Plastron yellow with more or less black round the edges of the plates. Zygomatic arch complete, broad. Hind feet more strongly webbed than in any other Terrapene I have had, the webs more extensive in the smaller specimen. Hind feet with four claws. A

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* Is the Florida Box Tortoise a distinct species by Einar Loennberg. Proc U. S. N. M. XIX No. 1107.

specimen from Riceboro, Ga., also apparently belongs here, length 140 mm, shell dark brown with narrow radiating yellow stripes; yellow on the keel not forming a continuous stripe, Plastron dark brown with light variegations. Head with round yellow spots, no stripes, zygomatic arch complete, claws on the hind feet three, and a notch showing termination of fourth digit, hind feet somewhat webbed, shape of the shell much as in the two Tallahassee specimens, perhaps a little shorter in proportion, flaring outwardly behind.

Terrapene ornata. This has the shell flatter and broader than the other forms, always without a keel. Color light brown with narrow radiating yellow lines on the carapace plastron brown, marked with yellowish lines arranged in regular pattern, posterior to the hinge they are mainly longitudinal while anterior to it they show a tendency to become transverse, zygomatic arch always incomplete. Hind claws always four. Hind feet always unwebbed. Some specimens, apparently males, have the first claw on each hind foot turned forward, while others, apparently females have it normal in position.

I may mention apropos of nothing that male tortoise have longer and thicker tails than the females, this feature is strongly marked in the genus Kinosternon, for instance and less strongly so in all Emydoid turtles I have examined.

Terrapene mexicana. This species I have not seen, its range is apparently confined to Mexico.

The range of the different forms of Tarrapene is roughly as follows:

Terrapene carolina. North-eastern U. S. east of the Mississippi, south to the Carolinas.

Terrapene triungis. Gulf coast and Mississippi valley from Georgia to the Rio Grande, North to Missouri.

Terrapene bauri. Florida and southern Georgia.

Terrapene major. Gulf coast, Georgia to the Rio Grande.

Terrapene ornata. Rocky mountains to Lake Michigan and Indiana, south to Chihuahua; in the southern part of its range it does not come east of Texas.

Specimens Examined.

Terrapene carolina. Eight alcoholic and numerous living specimens from Raleigh, N. C.

Terrapene triunguis. 33 living and 7 alcoholic specimens from Baker Co., Ga.; five living (three of them afterwards preserved) specimens from Colmesneil, Texas, one alcoholic from Hancock Co., Miss.

Terrapene bauri. Four living specimens from Orange Co., Fla., (three of them afterwards preserved), seven alcoholics from Hastings, Fla.; one alcoholic from Orlando, Fla., and one from Baker Co., Ga.

Terrapene major. Two from Tallahassee, Fla.; one from Riceboro, Ga.

Terrapene ornata. Several each from Waco, Texas, Austin, Texas, and Northern Chihuahua, Mexico.

CHAPEL HILL LIVERWORTS.

W. C. COKER.

North Carolina liverworts were not been neglected by the older generation of Botanists who brought so much credit to our Southern States in the early and middle parts of the last century. That excellent old Botanist, L. de Schweinitz, of Salem, not only did brilliant poineering work in the Fungi, but also found time to publish a valuable work on Hepaticeae of America (1826), many of the specimens described coming from this State. W. S. Sullivant, of Ohio, also described a number of North Carolina Hepaticeae in his publication of 1845. Dr. M. A. Curtis, of Hillsboro, N. C., in his catalogue of North Carolina plants* gives sixty-nine species of liverworts, twenty-three of which have so far been found at Chapel Hill. The remaining nine species in the following list are not given by Curtis.† This work of Curtis' is, so far as I know, the only list of North Carolina Hepaticeae. In 1899 Dr. D. S. Johnson collected a few Hepaticeae from around Beaufort, N. C., among them the interesting tropical form, Cololejeunea Jooriana, which has not been found further north.

In the steady of our list of Chapel Hill Hepaticeae, I have been greatly aided by Dr. Alexander W. Evans, of Yale University, who kindly identified a number of forms, confirmed my identification of others, and given informtion as to distribution. Species identified by Dr. Evans are so designated. The list follows.

Frullania virginica, Lehm. On trees and rocks. Common, often with rotifers in the saccate under lobes.

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* Geological and Natural History Survey of North Carolina. Part III. Raleigh, N. C. 1867.

† There is a fault in the printing in my copy of this quite rare pamphlet, by which several species are omitted. It is possible, therefore, that some of the species mentioned as not given by him were really in his list.

Archelejeunia clypeata, (Schwein) Schiffner. On rocks near streams.

Cololejeunia Biddlecormia (Aust) Evans. Bases of trees in very damp places. Vegetative parts in the center of the circular growth forms numerous gemmae and disappears as the outer part increases in circumference, in this respect resembling Lichens, which form soredia most abundantly in the central dying region. Not found by Curtis. (Identified by Evans.)

Radula obconica, Suliv. Given by Underwood in Gray's manual as extending from New Jersey to Ohio. Not found by Curtis. (Identified by Evans.)

Porella pinnata, L. On rocks close to where the spray reaches, or often immersed. Not found by Curtis.

Porrella platyphylla, Lindb. On trees and in woods, common. Vegetative branches closely oppressed, fruiting branches becoming erect and so lifting the capsules from the substratum. Not found by Curtis. (Identified by Evans.)

Trichocolea tomentella, Dumort. On ground along streams. Very rarely forming fruit.

Bazzania deflexa, Underw. Not found by Curtis.

Cephalozia multiflora, Spruce. Not found by Curtis.

Kantia trichomanis, S. F. Gray. On ground by streams. The tips of some of the branches bend upward and bear numerous gemmae on their tips. (Confirmed by Evans.)

Scapania nemerosa, Dumort. Common on ground in damp places. Here the ordinary leafy branches turn up slightly at the ends and bear dark masses of gemmae. Evans says of our Chapel Hill specimens, "Probably S. nemerosa although not quite typical."

Lophocolea heterophylla, Nees. (Identified by Evans.)

Diplophyllum albicans. Dumort. Var. taxifolium, Nees. On rotten wood. Not found by Curtis.

Chilocyphus ascendens, Hook and Wills (?).

Chilocyphus polyanthos, Corda (?). Evans says in reference to these two last species, "The two species of Chilocyphus I am in considerable doubt about. Number five is probably C. chilocyphus and number nine C. ascendens, but the leaves are more sharply lobed than I have ever seen before."

Plagiochila asplenoides, Dumort. On ground by brooks. Not common. (Confirmed by Evans).

Liochlaena lanceolata, Nees. Not found by Curtis.

Fossombronia salina, Lindb. Identified by Evans who says, "It seems to be preferable to F. salina Lindb. This species has a range extending from Connecticut along the coast to Florida and is apparently found in the West Indies also."

Pallavicinia Lyelli, S. F. Gray. Not common. (Confirmed by Evans).

Pellia epiphylla, Raddi. Common by streams.

Metzgeria conjugata, Lindb. Curtis gives M. furcata and M. conjugata for North Carolina. Gemmae are produced in abundance on marginal cells.

Anuera multifida, Dumort. In very damp places. I have found this on the floor of a mill race in South Carolina covered by several inches of swiftly flowing water. (Confirmed by Evans).

Aneura pinguis, Dumort. Forming large mats in springy places. (Confirmed by Evans).

Anthoceros laevis, L. Common.

Notothylas orbicularis, Sulliv. Not common in this region.

Marchantia polymorpha, L. Very rare here. Found in only one spot by Mr. H. A. Allard.

Fimbriara tenella, Nees. Not rare in low meadows.

Conocephalus conicus, Dumort. Plentiful, but rarely fruiting. The gametophyte contains abundant michoriza.

Asterella hemisphaerica, Beauv. Bases of stone walls on North side, and in damp old fields.

Dumortiera hirsuta, Nees. With or without air chambers, depending on location.

Riccia sp. Probably R. flutans. On damp open ground.

Sphaerocarpus terrestris, Smith. Edges of cultivated fields. The spores remain united in tetrads. Male plants minute, purplish.

RECENTLY DISCOVERED MINERAL LOCALITIES IN NORTH CAROLINA.

COLLIER COBB.

I have found the following minerals heretofore unknown in North Carolina:

Prase, green quartz, with included crystals of black tourmaline, one mile south of Franklin, Macon County.

Hausmannite and *Braunite*, Liberty, Randolph County, and Siler City, Chatham County.

Braunite, Hiltop, Surry County.

Reported at 138th meeting of the Elisha Mitchell Scientific Society, January 21st, 1902.

VOL. XX JUNE NO. 2

JOURNAL

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TO BE ENTERED AT THE POSTOFFICE AS SECOND CLASS MATTER.

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CHAPEL HILL, N. C.
PUBLISHED BY THE UNIVERSITY OF NORTH CAROLINA
1904

THE UNIVERSITY PRESS
CHAPEL HILL

JOURNAL

OF THE

ELISHA MITCHELL SCIENTIFIC SOCIETY

(Organ of the North Carolina Academy of Science)

TWENTIETH YEAR

1904

INORGANIC CHEMISTRY AND THE PHASE RULE.*

WILDER D. BANCROFT, PH.D.
Professor of Physical Chemistry, Cornell University.

As we look back over the history of chemistry, we see always the result of the two opposing forces, one that complicates and one that simplifies. The discovery of new facts makes the science more complex and more difficult to grasp. The discovery of new relations makes the science more simple because it enables us to correlate facts and thus to get a better grasp of the subject. The effect of the generalization in simplifying a single science or in unifying a group of sciences is overlooked by those who complain that the scientific man of the future will be a narrow specialist, knowing only a small part of a single division of one science. While this is always possible, it does not seem probable to me and I think it is much more likely that the chemist of the next generation will be a much better all-round man than any of us can hope to be.

In inorganic chemistry there is one great simplifying generalization with which we are all familiar, the Periodic Law. It has its imperfections and there are some who think that its

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*A lecture delivered before the Scientific Faculty and students, University of North Carolina, February 12th, 1904.

shortcomings over-balance its merits. Despite all hostile criticism, the periodic law is today the basis of classification for all advanced work in inorganic chemistry and its influence is marked even in the teaching of elementary chemistry. The periodic law enables us to correlate, more or less well, a large number of facts in regard to the properties of the elements and of their compounds. Yet people were slow in recognizing the full bearing of the statements that "the properties of the elements are a periodic function of their atomic weights" and I do not know what would happen if the law were being advanced today for the first time. There is a mathematical sound about the words "periodic function" which I fear might stamp the law as "too theoretical for the chemist."

While the Periodic Law enables the chemist to predict what the properties of certain substances will be, it concerns itself with these only and has nothing to do with the methods of preparation and separation in use by the chemist. This gap is filled by the second great simplifying generalization, the Phase Rule. So long as we are considering only the cases most studied by the chemist, those involving changes of concentration, pressure and temperature, we may state the phase rule in a relatively simple form: "When passive resistances to change are eliminated, the degrees of freedom of the system are two less than the difference between the number of phases and the number of components." Each chemically and physically distinct mass in the system constitutes a phase. Thus we may have the vapor phase, one or more liquid phases, and one or more solid phases. With ether and water we get two liquid phases; red and yellow phosphorus are two solid phases; so are ice and salt; while sodium sulphate decahydrate is only a single phase.

The statement that "the degrees of freedom are two less than the difference between the number of phases and the number of components" does not sound like a very important one. I can remember the time when I thought that people made a good deal of unnecessary fuss over the phase rule. It seemed to me an interesting mathematical relation but nothing more. That was ten years ago. Today, I am willing to say that the phase rule offers the rational basis for the classification of phenomena in inorganic chemistry and that it is perhaps the most valuable instrument of research that we possess. In view of the fact that probably ninety-nine per cent of the inorganic chemists make no use of the phase rule, these may seem rather bold statements. I am going to try to justify them. We will consider the phase rule first as a basis of classification and then as an instrument of research.

There are two criteria by which we may judge a method of classification. It must cover the whole ground and the divisions must be rational and not arbitrary. Our first division of the subject is by components. We consider separately systems composed of one, two, three, four or more components. Under each of these divisions we make further sub-heads depending on the number of phases. Thus under one-component systems we should take up first one-phase systems and should discuss the general and specific properties and characteristics of gases, liquids and solids. When considering the specific properties of specific substances, these substances can be taken in an order based on the Periodic Law. In the one-phase one-component systems and in all the other divisions we can arrange our material, in so far as is desirable, according to the Periodic Law. Under two-phase one-component systems, we classify liquid and vapor or boiling-point phenomena, solid and vapor or sublimation phenomena, liquid and solid or freezing-point phenomena, solid and solid or allotropic phenomena. Under three phases we describe such phenomena as the freezing-point of water, the equilibrium between monoclinic sulphur, rhombic sulphur and vapor or melt. Under this same heading comes the general question of monotropic and enantiotropic forms. While chemical action appears to be excluded in one-component systems, such polymerized vapors as acetic acid, sulphur and nitrogen dioxide introduce changes involving the law of definite and multiple proportions, and form an introduction to two-component systems.

Under two-component one-phase systems we have mixtures of indifferent gases, dissociation of gases, mixtures of liquids with and without formation of compounds, solid solutions. With solid and vapor we can have a dissociating solid compound, or a compound existing in the vapor only, such as the oxides of carbon in equilibrium with carbon, or nickel carbonyl. Under solution and vapor we get Henry's law, the law of van't Hoff and Raoult, the phenomena of osmotic pressure, all boiling-point phenoma and the theory of electrolytic dissociation. The other cases of two-phase equilibria involve solubility under pressure. With three phases we have the dissociation pressures of compounds such as hydrated salts, calcium carbonate, etc.; solubility relations, freezing-point determinations, etc.; while with four phases we get the characteristic properties of the quadruple point.

With three components we get more of the characteristic reactions of chemistry. The reaction between carbon monoxide and water belongs under the heading of vapor phase; the formation of esters in organic chemistry is referred to systems involving a liquid phase; the solubility of gases in solutions belongs under two phases, liquid and vapor. With three components and three phases, we get the precipitation of a salt by another salt or by a liquid, the conditions of existence of double salts, the blast-furnace reactions, the reduction of chlorides or sulphides by hydrogen, the facts in regard to shaking out, many of the facts concerning dyeing, fractional crystallization, occlusion, theory of indicators, etc.

With four components we get the solubility changes with two salts having no ion in common, fractional precipitation and also many cases of fractional crystallization. A very large number of chemical reactions involve only four components and therefore come in here.

It will probably seem as though I have laid more stress on physical chemistry than on inorganic chemistry. This is however more apparent than real. Inorganic chemistry, as a present practiced, consists chiefly in the preparation and study of certain compounds, and to a lesser extent in the study of reactions, usually a qualitative study. In so far as we are dealing with single substances, all that is inorganic chemistry as well as much more finds its place under one-component systems. The preparation of compounds involves phase separation by definition and is therefore included under what is called physical chemistry. The study of reactions is physical chemistry pure and simple. In fact, inorganic chemistry is merely one part of what should be called chemistry, but which unfortunately is called physical chemistry. I quite appreciate that many people take physical chemistry to mean the theory of dilute solutions. That is a very natural mistake which is made even by some who call themselves physical chemists. If one accepts my definition of physical chemistry as the science of chemistry, it is clear that it includes inorganic chemistry and that it includes very much more than the theory of dilute solutions.

I have tried to show that the phase rule offers a satisfactory basis for the classification of practically all the phenomena of inorganic chemistry. For the present, we cannot include much of organic chemistry any more than we can include potassium chlorate, because we are dealing with passive resistances to change in these cases. I look upon this as a temporary limitation and I have hopes that some day it will be possible to present organic chemistry as a system made up of carbon, hydrogen and oxygen as the independently variable components. The recent work of Sabatier and Senderens on the catalytic action of nickel and copper makes the application of the phase rule to organic chemistry a problem of today; but the work has not yet been done and for that reason I have discussed the phase rule only in its bearing on the classification of inorganic chemistry. It is now in order to ask what use the phase rule has been and will be in promoting research.

We will start with an apparently complicated case of solutions containing three or more components. Here the phase rule has brought order out of chaos. It is merely a question of time to determine the conditions of existence for all the possible compounds or solid solutions. The experiments of van't Hoff on the Stassfurt deposits have shown what the composition of the original sea was, why the salts have come down as they have, and even the temperature at which the water was evaporated. His work has furnisned the scientific explanation for the methods of separation worked out empirically at Stassfurt and led to new methods.

There are today many chemists who throw up their hands in despair when they encounter a double salt which cannot be recrystallized without change and yet this is a very simple problem with the phase rule to guide one. The phase rule enables us to tell whether a given solid is a mixture, compound or solid solution. When we reflect on the number of imaginary double salts and basic salts which encumber the literature, we see how sorely such a criterion has been needed in the past. We are now able to attack the problems of fractional crystallization and precipitation in a rational manner.

Today new methods of separating rare earths are coming into use; but, in the past, it has been largely a matter of fractional crystallization and of fractional precipitation. These methods have been slow and not very certain; but how much of that is due to the man and how much to the method? How many of those who have worked with rare earths could take such a relatively simple problem as to separate NaCl and KCl by fractional crystallization, getting the whole of each pure? If one cannot do that, why should one expect to make rapid headway in the separation of an unknown number of unknown substances, which may or may not crystallize together as compounds or solid solutions? Here is a simple instance of the confusion which may easily arise. If one takes a certain solution of copper chloride, potassium chloride and water, cool it to a certain temperature and filter, there will be left on the filter the red salt $KClCuCl_2$. If the solution is cooled to a slightly lower temperature before filtering, the crystals will be a mixture of the red salt and a green salt $CuCl_2.2KCl.2H_2O$. If the filtration had taken place at a still lower temperature, the precipitate would have been the green salt alone. That is confusing enough but it is not all. If the red salt is washed with water, the green salt is formed while cupric chloride will go into solution. If the green salt is washed with water, a white salt, KCl, is left behind. This is bad enough when the three salts are colored differently; but it is nothing to the difficulties that would beset a man if the salts were all colorless, had the same properties, and could be distinguished chiefly by their unknown atomic weights. This is not mere fancy. I could cite an instance in which two distinguished chemists analyzed what was in all probability a mixture of two salts, believing it to be homogeneous. They were thus led to assume the existence of two new elements, the presence of which could not be shown in any other way.

The whole question of alloys has been put on a rational basis by means of the phase rule. Roozeboom has outlined the methods for studying iron and steel; Heycock and Neville have cleared up the question of the bronzes. We can now distinguish in a way that we never could have done before between states of hysteresis and states of equilibrium. When we eliminate hysteresis, the densities of alloys vary with the composition just as they should. It seems not unreasonable to hope that the tensile strength and other engineering properties of annealed alloys will also vary regularly with the percentage composition. The experience we have gained with salt solutions and with fused alloys will stand us in good stead when we come to consider fused magmas. I feel certain that many of the problems of geology can be solved only by an intelligent application of the phase rule. Recently some people have tried to make certain minerals synthetically by fusing together the components in the proportions in which they occur in the mineral. This can be successful only in case the chilled melt is annealed thoroughly. Merely allowing the melt to cool will not give the desired result.

Another matter in which the phase rule has been of great value is in analysis in cases where a pure compound cannot be isolated. Under these circumstances, the ordinary methods of gravimetric and volumetric analysis are inapplicable. By methods based on the phase rule, it has been possible to determine with accuracy the composition of compounds crystallizing from a molten mass of metal.

Analyses of efflorescent salts containing water or acid of crystallization are necessarily inaccurate because there is no way of drying the compounds enough to remove all the mother liquor without running the danger of removing some of the volatile component. By the new methods this difficulty no longer exists because the compound can now be analyzed while in the solution.

As yet no one has applied these methods to the analysis of colloidal precipitates, but there seems to be no reason to suppose that this cannot be done. The methods of the phase rule have already been used with success in determining the composition of hydrated beryllium sulphate. The whole question of colloidal precipitates has taken on a new aspect since van Bemmelen began the study of the equilibrium relations with reference to the phase rule.

No matter where one turns, in the whole field of inorganic chemistry, one finds the phase rule useful as an instrument of research. This has come about in the last few years and is but an earnest of what is to be done in the future. When the domain of the phase rule has been extended to cover the whole of organic chemistry and of electrochemistry, every one will then admit the truth of my theses "that the phase rule offers the rational basis for the classification of all chemical phenomena and that it is perhaps the most valuable instrument of research that we possess."

EAST AMERICAN THORNS.*

W. W. ASHE.

TOMENTOSAE.

CRATAEGUS OBESA. A slender narrow crowned tree, seldom exceeding 4 m in height, with nearly black scaly bark on the armed trunk and slender orange or russet pubescent twigs sparingly armed with short 2–3 cm-long thorns. Leaves broadly ovate or nearly orbicular, 7–10 cm long, 5–7 cm wide, rounded or broadly cuneate at base, with many pairs of short ascending notches above the middle, dark green above, paler and tomentose beneath, petioles margined above. Flowers, appearing usually the first week in June in large compound tomentose corymbs, are about 16 mm wide; stamens small, 20. Fruit, borne in large compound clusters, ripening in September and falling after the leaves, is globose or slightly oblong, 8–9 mm thick, scarlet, often capped by the very small narrow reflexed lobes, or the lobes and tube projection deciduous; fleshy pulpy, seed usually 2, hemispherical.

St. Louis County, Missouri. Dr. N. M. Glatfelter. Apparently frequent in eastern Missouri.

TENUIFOLIAE.

CRATAEGUS UBER. A slender tree 3–6 m high with thin gray scaly bark on the trunk, and slender dull chestnut twigs sparingly armed with 3–6 cm-long thorns. Leaves thin, glabrous, ovate or oval, 5–6 cm long, 4-6 cm wide, rounded or narrowed at the broad, often oblique base, several pairs of short acute ascending lobes from near the base; petiole slender, 3–4 cm long. Flowers, appearing about the 20th of May in small loose compound many-flowered pubescent corymbs, are about 20 mm wide; stamens 5–8, usually 5, anthers purple. Fruit, borne in small compound clusters on long slender

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* Issued June 15, 1904.

drooping pedicels, ripening late in September and falling with and before the leaves, is oblong, 14–18 mm long, 12-15 mm thick, full and rounded at the ends, dark dull red, mottled with orange at apex, capped by the long narrow brown spreading or ascending lobes which are finely and sharply serrate above the middle; flesh firm, white, juicy and sweet, seed 4–5, 7–8 mm long, narrowed at base, the face narrow.

Summerville, St. Clair Co., Mich. W. W. Ashe, Oct., 1902; C. K. Dodge and W. W. Ashe, Oct. 1903; C. K. Dodge, May, 1903.

CRATAEGUS PERLEVIS. A shrub seldom 3 m high, with ascending branches and purple-brown twigs, armed with numerous 2–5 cm-long thorns. Mature leaves glabrous, pale green, thin but firm, broadly to narrowly ovate, 3–5 cm long, 2.5–5 cm wide, rounded at the broad base, 3 to 4 pairs of short acute lobes, sharply and finely serrate; petiole short but slender. Flowers, appearing the middle of May in glabrous, many-flowered compound corymbs, are about 15 mm wide; stamens 8–10: anthers light red-purple. Fruit, ripening late in September and falling in September and October with and after the leaves, borne in small compound or simple clusters on very slender, rather long pedicels, is pyriform, obovate or rarely oblong, 11–13 mm long, 8–12 mm thick, dark dull red or scarlet, the apex usually much blotched with orange or russet, the narrow entire glabrous lobes short-stalked and appressed.

Berks County, Pennsylvania. Sept., 1901, W. W. Ashe; May and Sept., 1902, May and Sept., 1903, C. L. Gruber; W. W. Ashe, Sept., 1903.

CRATAEGUS OTIOSA. A much branched shrub 3 m in height with a large spreading crown, and slender glabrous, dull red-brown twigs sparingly armed with 2 cm long thorns. Leaves glabrous, rather firm, broadly oval to ovate, the blades 4–6 cm long, 3.5–5 cm wide, truncate to broadly cuneate at base, sharply doubly serrate; many pairs of short broad ascending lobes from near the base; petiole slender, 2–3.5

cm long. Flowers, appearing the last of May in large loose compound many-flowered glabrous clusters, are about 16 mm wide, stamens 5–8. Fruit, borne in loose compound many-fruited pendent clusters, ripening from the first to the middle of October, is oblong, 11–13 mm long, 8–10 mm thick, russet or at length scarlet, the flesh firm, white and juicy; lobes narrow, entire, reflexed or deciduous, seed 3 or 4, small.

Summerville, St. Clair County, Michigan; W. W. Ashe and C. K. Dodge, September, 1902, and October, 1903; C. K. Dodge, May and September, 1903.

CRATAEGUS RETRUSA. A shrubby tree seldom more than 4 m in height with slender chestnut twigs and stout 2–4 cm-long slender ascending thorns. Leaves thin, glabrous, ovate or broadly ovate, 4–6 cm long, 3.5–4.5 cm wide, rounded or broadly cuneate at base, with several pairs of short broad notches, finely doubly serrate. The flowers, appearing about the 20th of May in loose glabrous compound many-flowered clusters, are about 22 mm wide; stamens 5–7, anthers pale purple. Fruit, borne in loose few-fruited slightly compound long-pediceled clusters and ripening late in September, is oblong or usually obovate, full and rounded at the ends, 13–15 mm long, 12–14 mm thick, orange-scarlet, often mottled with orange at apex, capped by the erect fleshy bases of the lobes; flesh thick, sweet, orange; seed 3–4, thick and coarse, grooved on back, about 7 mm long.

Summerville, St. Clair County, Michigan, where very common. C. K. Dodge and W. W. Ashe, Sept., 1902; Oct., 1903; C. K. Dodge, May, 1903, Sept., 1903.

CRATAEGUS GRAVIS. A tree 6–7 m high with thorny scaly bark on the trunk, ascending fluted gray branches, and stout dull chestnut glabrous twigs, freely armed with stout 3–4 cm-long slightly recurved thorns. Leaves thick, firm, bright green, pubescent above when young, otherwise glabrous, ovate to nearly orbicular, 3–5 cm long, 2.5–5 cm wide, rounded or obtuse at base, finely and obtusely doubly serrate, several pairs of very shallow notches, turning dull yellow or brown and falling in October. Flowers, appearing the last week in May in small loose slightly compound glabrous clusters, are about 20 mm wide; stamens 10, seldom 5–10, anthers rose-purple. Fruit, borne in small nearly simple clusters on rather long spreading pedicels and ripening in October, is slightly oblong, 8–10 mm long and 7–9 mm thick, flattened at the ends, dark red or crimson, seldom with orange spots at apex, capped by the closely sessile appressed lanceolate entire lobes, which are often appressed pubescent above; flesh firm, sweet, juicy, pale yellow; seed 4–5, small, 5–6 mm long, sometimes grooved on the back.

Port Huron, Michigan: common. W. W. Ashe and C. K. Dodge, September, 1902, October, 1903; C. K. Dodge, May and September, 1902, and 1903.

CRATAEGUS SEQUAX. Arborescent, 4 m in height, with a round crown of ascending flexuous branches; the purplish-brown usually glabrous twigs armed with many 1–5 cm-long rather stout thorns. Leaves soon nearly or quite glabrous, firm, deltoid, broadly ovate or ovate, 3–6 cm long, 2.7–5.5 cm wide, rounded or truncate at the base, usually 3–4 short acute lobes, sharply serrate, petiole slender, rarely puberulent. Flowers, appearing the second week in May in small compact slightly compound cymes, are about 20 mm wide; stamens 5–10, frequently 8, anthers purple. Fruit, ripening the last of September and falling with and after the leaves and borne in short compact usually simple clusters, is globose or subglobose 12–15 mm long and thick, dark red or crimson, often blotched with green or russet at the apex, the narrow subentire lobes spreading, reflexed or ascending.

C. L. Gruber and W. W. Ashe, Berks county, Pa.

CRATAEGUS VITTATA. Arborescent, 4–5 m high, with rather stout red-brown glabrous twigs sparingly armed with 5–6 cm-long stout thorns. Leaves ample, thin, firm, soon glabrous, broadly oval, the blades 5–7 cm long, 5–6 cm wide, rounded or truncate at the broad base, abruptly acute at apex, 3–4 pairs of broad short lobes; petioles very slender, 2.5–4 cm long. Flowers, appearing the first week in May in glabrous simple or compound compact corymbs, are from 15–20 mm wide; stamens 5–10, usually 8–10; anthers bright red-purple. Fruit, ripening early in September and gradually falling before the leaves, borne in simple few-fruited clusters on slender 1–2 cm-long pedicels, is subglobose or short cylindrous, 14–18 mm thick and long, red scarlet blotched with olive or russet, sparingly glaucous, capped with the narrow glabrous entire or serrulate spreading or erect lobes; flesh soft, thick, edible, acid, orange, often tinged with pink; seed 3–4, 6–8 mm long, deeply grooved on the back.

Pennsylvania, Berks county, frequent. W. W. Ashe and C. L. Gruber, Sept., 1902, and Sept., 1903; C. L. Gruber May and Sept., 1902, and May, June and Sept., 1903.

CRATAEGUS MINIATA. A shrub 2–3 m in height with ascending branches, with dark brown glabrous slender twigs armed with 3–4-cm long slender thorns. Leaves thin, glabrous, dark green, oval or broadly oval, 4–6 cm long, 3–5 cm wide, rounded at the usually broad base, abruptly acuminate at apex, 4–6 pairs of very short lobes beginning near the base. Flowers, appearing about the middle of May in glabrous compound rather small corymbs, are about 15 mm wide; stamens 5–10, usually 8; anthers pink. Fruit, borne in small compact usually compound clusters, ripening early in September and falling with the leaves, is oblong, 12–14 mm long, 9–13 mm thick, scarlet, sometimes spotted with olive or russet at the apex, glossy, capped with the small glabrous narrow entire reflexed or spreading lobes, or lobes deciduous; flesh yellow or pinkish; seed 2–3, 6–7 mm long, grooved on the back.

Pennsylvania, Berks county. C. L. Gruber and W. W. Ashe.

CRATAEGUS RUFIPES. A shrub about 2 m in height with glossy slender purplish-red glabrous nearly straight twigs, armed with numerous 2–4 cm-long thorns. Leaves thin but firm, bright green, lucid, when young silky, pubescent above, but at length glabrous, the blades ovate to oblong ovate, 5–7 cm long, 4–6 cm wide, rounded, rarely truncate or acute at base, acuminate at apex, 4–7 short very acute lobes beginning near the broad base; petiole stout, usually margined and glandular, purplish, as is the midrib. Flowers, appearing about the middle of May in many 6–20-flowered compound or simple glabrous corymbs are about 15 mm wide; stamens 5–8, anthers dark rose. Fruit, borne in small simple or compound clusters, ripening about the middle of September, is oblong, 12–14 mm long, 9–11 mm thick, scarlet frequently mottled with green or russet at the apex; the linear subentire nearly glabrous lobes reflexed; flesh soft, orange or reddish; seed 2–3, 6–7 mm long, 2–4 shallow grooves on back.

Pennsylvania, Berks county. C. L. Gruber and W. W. Ashe, Sept., 1903, C. L. Gruber, May and July, 1903.

CRATAEGUS MULTIFIDA. A shrub 1-2 m in height, with slender slightly zigzag red-brown glabrous twigs, sparingly armed with 4–7 cm-long thorns. The leaves are thin, firm, bright green, soon glabrous, broadly ovate in outline, the blades 4–5.5 cm wide, acuminate at apex, round or cordate, seldom obtuse at the broad base, 3–5 pairs of deep acuminate lobes, the lower pair spreading and with reflexed tips, sharply serrate or doubly serrate. Flowers, appearing the last week in May in rather small compact slightly compound glabrous corymbs, are about 15 mm wide; stamens usually 10. Fruit, borne in small compact compound drooping clusters, ripening late in September and falling with and after the leaves, is oblong, 11–14 mm long, 9–11 mm thick, rounded at the ends, crimson, capped by the closely sessile appressed, narrowly triangular usually entire lobes; flesh yellow, soft and pulpy, seed 4–5 mm, 6–7 mm long.

Sandy soil near the St. Clair River, Port Huron, Mich.

W. W. Ashe, and C. K. Dodge, September 1902; C. K. Dodge May 1902, May and September 1903.

CRATAEGUS TENERA. Arborescent in habit, about 3 m high, with rather short spreading branches; twigs red-brown, freely armed with short rather stout 2–3 cm-long ascending thorns, Leaves glabrous, thin, ovate or broadly ovate, the blades 3–5 cm long, rounded or truncate at the broad serrate base, 3–4 pairs of short acute lobes, finely and sharply serrate. Inflorescence a many-flowered very compound glabrous drooping corymb; stamens small, usually 5–8. Fruit, borne in large compact compound drooping clusters, is oblong, 11–13 mm long, 9-10 mm thick, bright scarlet, sparingly pruinose, ripens about the the first of October and at once falls; lobes very long and narrow, usually entire, spreading, or are with deciduous tips and keeled base; flesh thick, pale yellow, white or pink, at length soft and pulpy, seed 3, rounded on the slightly grooved back, small, 5–6 mm long.

Sandusky, Ohio; E. Mosely and W. W. Ashe.

CRATAEGUS MARCIDA. Arborescent, 3–4 m high, with horizontal branches, and red-brown glabrous sparingly armed twigs. Leaves thick, firm, dark green and lucid above, glabrous, ovate, narrowed to the acute point from the broad rounded base, few shallow lobes, sharply doubly serrate, 4–6 cm long, the lower pairs of thin veins, arched. Inflorescence a large compound many-flowered glabrous corymb; stamens 10. Fruit, borne in large loose compound drooping corymbs, is depressed globose, 13-15 mm thick, 11-12 mm long, dark crimson with green apex, glaucous, lobes sub-entire, spreading from a broad base; flesh deep orange, firm and juicy; seed usually 4, shallow groved on the back.

Ohio: Leverettsburg, W. W. Ashe; Sandusky, E Mosely and W. W. Ashe; Garrettsville, R. J. Webb and W. W. Ashe. This beautiful thorn will probably prove to be common throughout Northern Ohio.

CRATAEGUS PROPINQUA. Arborescent in habit, 2-3 m high, branches slender, spreading, twigs slender, glabrous, red-brown, armed with slender 3-4 cm-long thorns. Leaves glabrous, thin but firm, light green, broadly ovate or rhombic, rounded or cuneate at the subentire base, the blades 3-5 cm long, very few shallow ascending lobes and deeply impressed straight ascending primary veins; sharply doubly serrate.

Inflorescence a 5-10-flowered slightly compound glabrous corymb; stamens 10. Fruit, borne in simple few-fruited clusters, is globose; 12-13 mm thick, green, russet and dull red, capped by the narrowly triangular, ascending, dry, subentire lobes; flesh pale yellow, firm; seed usually 3, 7-8 mm long, with shallow furrows on the broad rounded back.

Hillsides, Milan, Ohio. While this plant has characters which ally it to the Pruinosae, as is the case also with the preceding, it is probably best placed with the Tenuifoliae.

PRUINOSAE.

CRATAEGUS INGRATA. A bushy tree, 3-5 m in height, with red-brown twigs, occasionally slightly pubescent the first spring, but glabrous by fall, armed with numerous short 2-4 cm-long stout thorns. Leaves thin, pale green, pubescent below, especially on the viens, when young, ovate or broadly ovate, the blades 5-9 cm long, lobed above the middle with few very short teeth, rounded at the base, sharply serrate, petiole slender, pubescent, 3-4 cm long. Flowers, appearing about May 18th, in nearly simple 5-10-flowered, pubescent corymbs, are about 18 mm wide: stamens 20, anthers white. Fruit, borne in simple clusters on slender 2-3 cm-long pedicels, is subglobose, 12-14 mm thick, dull red; tube slightly projecting, the narrow lobes reflexed or deciduous: seed 3-5, the large ones ridged on the back, 7-8 mm long, narrowed at the base.

Near Pittsburg, Pennsylvania. J. A. Shafer, May 18, and October 26, 1902. J. A. Shafer and W. W. Ashe, September, 1901.

CRATAEGUS SITIENS. A stoloniferous shrub, seldom arborescent, forming thickets 2-4 m in height with thorny nearly black scaly bark and very slender brown-purple geniculate twigs, fully armed with slender 3-4 cm-long thorns. Leaves glabrous, thin, broadly ovate, truncate or rounded at the very broad base, 3-5 cm long and wide, with many pairs of deep lobes above the base, coarsely serrate. Petioles slender, 2-3 cm long. The flowers, appearing about May 20th in simple glabrous, 3-5-flowered cymes, are about 24 mm wide; stamens 20, anthers purple. The fruit, solitary or in few-fruited clusters on strict slender 1.5 to 2 cm-long pedicels, is obovate, 12-14 mm thick, green mottled with russet; cavity very broad, the short broad entire lobes reflexed; the tube long projecting or often deciduous; flesh hard and green, seed 4-5, small, 6 mm long, lateral faces broad and flat.

St. Clair County, Michigan. Not common. W. W. Ashe and C. K. Dodge, Oct., 1902; C. K. Dodge May 23, 1903, Oct., 1903.

BOYNTONIANAE.

CRATAEGUS RESES. A many-stemmed shrub, forming thickets about 2 m high, the rather stout chesnut twigs glabrous, and like the stems almost unarmed. Leaves glabrous, thick, soft, very dark green above, very pale beneath, the blades elliptic or ovate or oblong ovate, 6-9 cm long, 4-6 cm wide, gradually narrowed from near the middle to the narrow rounded base, crenate, 2-3 pairs of short broad obtuse notches above the middle, turning red bronze or yellow and falling late in autumn; petiole short and stout, winged above. Flowers appear about the middle of May in simple long-pedicelled glabrous 5-10-flowered cymes; stamens 10; anthers cream. Fruit ripening in October and falling largely after the leaves, borne in 1-5 fruited clusters, on long stout, often strict pedicels, is subglobose, usually slightly narrowed at the base, 13-16 mm thick, dark red mottled with russet or green, dull and glaucous, or glossy, capped by the oblong, coarsely glandular serrate glabrous lobes borne on the projecting tube, or often lobes deciduous; flesh firm, orange or reddish, bitter; seed usually 4-5, 7-8 mm long, shallow 1-3 grooved on the back.

Pennsylvania, Berks County: C. L. Gruber and W. W. Ashe, Sept., 1903; C. L. Gruber, May, 1903.

AMARAE.

Crataegus olida. A flat bushy tree 5 m in height, with glabrous bright purple-brown twigs armed with numerous slender 4-5 cm-long darker thorns. Leaves glabrous, thick and firm, the blades 4-6 cm long, ovate, obovate or nearly orbicular, 2-3 pairs of shallow lobes above the middle, obtusely serrate nearly to the base; petiole stout, 1.5-2 cm long, broadly margined and glandular. The flowers are borne in 5-12 flowered glabrous compound strict corymbs; stamens normally 10, filaments stout, 5-6 mm long, lobes narrowly triangular, subentire, reflexed after anthesis. Fruit, falling after the leaves, and borne in slightly compound clusters, is obovate or pyriform, 15-19 mm long, 14-16 mm thick, golden yellow; flesh yellow, firm, slightly bitter; seed 2-4, usually 3, 7-8 mm long, thick and coarse, the broad back grooved.

J. A. Shafer, May 30 and Nov. 9, 1902; Pyler Falls, Pennsylvania.

INACTIVE THORIUM.*

FRITZ ZERBAN, PH.D., (CARNEGIE RESEARCH ASSISTANT).

It was soon after the discovery of the well-known X-rays by Roentgen, that Becquerel, in Paris, observed that remarkable property of Uranium potassium sulphate by which it affected the photographic plate through light-tight black paper, when the sun shone on the salt. At first he thought that this action was brought about by the fluorescence of the Uranium salt, but very soon discovered that nonfluorescent Uranium compounds and the metal itself effected the same action, and that the concurrence of the sun's rays was not necessary, the aforementioned phenomenon appearing also in a thoroughly dark room. He called this peculiar property of the Uranium "radioactivity", and for the rays, which produce the blackening of the photographic plate, the name of "Becquerel rays" was adopted. It was shown then that the Uranium compounds had still another remarkable property, namely of diminishing the conductivity of the air for electricity, so that a charged electroscope loses its charge more rapidly than usual, if a Uranium compound is brought near it. Thirdly, the Becquerel rays excite, like the X-rays, the fluorescence of a Barium platinocyanide screen.

Three methods for testing the radioactivity of bodies were thus acquired and different investigators discovered, besides the Uranium, some other radioactive substances. Mr. and Mrs. Curie found in Pitchblende two such bodies; Polonium, which is similar to Bismuth, and Radium, which soon brought to its discoverers great fame all over the world. The Radium occurs with Barium, and is separated from it by very laborious and protracted operations. As Radium is the most strongly

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* Read before the North Carolina Academy of Science, Wake Forest Meeting, May 14th, 1904.

radioactive body, one can show with its salts in the best manner the action of the Becquerel rays.

According to the investigations of Rutherford and his collaborators, the different actions of the radioactive bodies are not caused by one kind of rays, but by different ones. The rays which cause the discharge of the electroscope he called α-rays. They are easily absorbed by different substances and only slightly deflected by a magnet.

The β-rays on the other hand produce chiefly the photographic action, even penetrating thin metal sheets, wood, and so on, and are deviated easily in a magnetic field. Rutherford found also a third kind of rays, the γ-rays, the source of which is not clearly defined. Perhaps these, according to the suggestion of Dr. Baskerville, are derived from the β-rays, as the Roentgen rays arise from the cathode rays. A discussion of this matter need not hold our attention today however.

It is noteworthy indeed, that the radioactive substances emit not only *rays*, but *material particles* too, in form of a gas. It may be swept along by a stream of air blown over the substance and follows its course, unlike the light rays. It also diminishes the conductivity of the air. As a real gas it has been condensed to a liquid boiling at about 135° below zero. Rutherford called this very interesting property of the radioactive bodies "emanation".

Rutherford performed his preliminary experiments not with Radium, Uranium or Polonium, but with another radioactive substance, Thorium. Mrs. Curie and G. C. Schmidt had found, independently of each other, that the Thorium compounds are also radioactive. Some time later Debierne discovered in Pitchblende a body similar to Thorium. It gave all the reactions of real Thoria: precipitation by Ammonia, Alkali, Ammonium sulphide, also by oxalic acid, strong acids being present, and in neutral solution by Sodium thiosulphate and Hydrogen dioxide. Its hydroxide was insoluble in hydrofluoric acid and Potassium fluoride. But differing from the ordinary Thorium it was extremely and permanently active.

Debierne assumed it to be a new element and gave it the name "Actinium".

Now the question was raised, whether the radioactivity of the Thorium compounds was caused by admixture of a little quantity of Actinium, and whether Thorium obtained by any means whatever is in every case radioactive.

Rutherford tried to answer the question, whence the activity of the Thoria came. He, by precipitation of Thoria with ammonia, obtained a filtrate which was much more radioactive than the precipitate. He said that the activity of Thorium is due to the body contained in the liquid and called it Th X. Subsequent investigations from this savant indicate the continued regeneration of Th X. In the laboratory of the University of North Carolina we have experiments planned which promise an explanation of this, so we may defer further consideration for the present.

Professor Hofmann, in Munich, and I, attacked the problem and the results of our investigations are briefly presented here. Incidentally it must be noticed that the Thorium, of which I am talking, means the old Thorium, the elementary nature of which is now getting very precarious by the splendid investigations of Dr. Baskerville which are astonishing all the world.

To decide the questions mentioned above it was at first necessary to study the minerals, from which the Thorium preparations to be examined were obtained. All the preceding investigations were made with commercial Thorium compounds which came from monazite sand, exclusively I think. We examined the Thorium obtained from the following minerals: bröggerite, cleveite, euxenite, samarskite, fergusonite, xenotine, thorite, orangite, aschynite, monazite sand, gadolinite, orthite and yttrotitanite. The Thoria was extracted from these minerals by different methods according to their composition. It was always separated from the other rare earths by dissolving its oxalate in a hot solution of ammonium oxalate and precipitating the Thoria in the cooled and diluted filtrate by hydrochloric acid.

In this manner we obtained from the four first mentioned minerals, bröggerite, cleveite, euxenite and samarskite, some strong and some very strong active Thorium preparations, far surpassing the activity of the usual Thorium compounds. The assumption of the presence of Actinium therein was tenable, so we tried then, like Mr. and Mrs. Curie with Radium, to separate the Actinium by means of fractionation. And to all appearance we succeeded in this way, for we could accumulate the activity in one part of the fractions. It happened by fractional precipitation with Potassium sulphate, Sodium thiosulphate, Potassium chromate, Hydrogen dioxide, and fractional solution in Ammonium carbonate.

Our work was suspended during the vacation in 1901. On resumption of the investigations our previously very strongly active preparations had lost nearly all their activity upon the photographic plate and the electroscope. Thus it was shown that the Thorium could not possibly contain a primarily active body. For these, as for instance Radium and Actinium, behave quite differently. Immediately after their separation they show a certain quantity of radioactivity, which increases within a few weeks to a maximum, and then remains *constant* during several years, at least according to our measuring methods. But Thorium behaved quite differently. Its activity rather diminished, and then indeed it reserved constantly a very little activity. The β-, or photographic action fell down to an insignificant amount, whereas the α-radiation assumed about the value of the weak Uranium radiation.

As therefore Thorium evidently is not a primarily radioactive body, the further question was to be decided: where does the activity of the Thorium compounds come from? The investigation of the other minerals gave us the key to this problem. The four first mentioned minerals contain a great deal of Uranium in comparison with the amount of Thorium present. We found furthermore: the more Uranium and the less Thorium a mineral contains, the more active is the Thorium obtained from it.

It was quite important to secure Thoria from several minerals containing *no* Uranium, as from Norwegian gadolinite, orthite and yttrotitanite. Thorium separated from these minerals is inactive upon the plate and the electroscope. Mr. Curie was kind enough to make a control determination of the activity of one of these preparations, and he also found it practically inactive or if possessing any activity at all, its value is only one seventh of the activity ever observed.

The inactive Thorium shows all chemical properties of ordinary Thorium. To prove that it was really Thorium I made an approximate determination of its atomic weight, and found 222.7. This figure is of value mainly, as it indicates an element with an atomic weight above 200.

It is most probable that the Thorium itself does not possess any primary activity at all, but that it receives its activity from other primarily active bodies like Uranium or Radium, or even from the *air*, which, according to the investigations of Elster and Geitel contains *always* and *everywhere*, more or less radioactive particles. We succeeded in securing a further very important proof of our opinion, by producing artificially active Thorium from an inactive one, and by showing that this artificially active Thorium behaves in every way like the natural active Thorium.

The experiments were made as follows: to a solution of inactive Thorium nitrate a ten to twenty-fold excess of Uranium nitrate in solution was added; the mixture was then kept about two weeks, and the thoria precipitated with oxalic acid. The well washed and burned Thorium preparation behaved then exactly like the thoria of bröggerite and cleveite. It showed a very considerable amount of α- and β-activity. But after a year the β-radiation disappeared nearly altogether, and the α-radiation recovered gradually a small, but finally constant value. In a similar way as with Uranium, we rendered thoria active by means of Polonium.

Although *per se* inactive Thorim can be obtained of some minerals, and although, on the other hand, the at first strongly active Thorium loses the largest part of its activity within a few months, we have not yet secured Thorium entirely free from the last remnant of activity. In company with Dr. Baskerville I made some experiments about this, using the property of Barium and Lead to take with them the activity, when precipitated in a mixture with an active salt by means of sulphuric acid or Hydrogen sulphide. In these experiments we did not use the original Thorium, but its three components, about which Dr. Baskerville will speak to you in a few moments. We dissolved a little quantity each of Berzelium, Thorium and Carolinium salt, one of which must surely be the bearer of the original Thorium activity, added a large excess of Barium chloride, kept the whole during three days and then precipitated the Barium with sulphuric acid. The Berzelium, Thorium and Carolinium obtained from the filtrate were then nearly inactive, but within two weeks they regained their original activity. Nor did we succeed in removing the activity from the original Thorium by adding a large excess of Lead salt and precipitating the latter with Hydrogen sulphide.

While one may secure inactive Thorium direct from certain minerals, it has been quite impossible so far to remove the last remnant of activity from Thorium that has once been active.

As in the meantime Dr. Baskerville happened to divide the old Thorium into three constituents, it is very interesting indeed to investigate what part the three new elements take in the radioactivity of the old Thorium. So far it has been found that all three, although not in the same degree, are active. But possibly the new elements are not yet pure enough; hence we hope by further methods of purification to reach that point, so that we can give with the description of all their properties also this of the degree of their activity.

In the list of members of the North Carolina Academy of Science, published in the last issue of this journal, the following names were omitted;

Stevens, F. L.,	West Raleigh.
Stevens, Mrs. F. L.,	West Raleigh.
Venable, Francis P.,	Chapel Hill.
Wilson, H. V.,	Chapel Hill.
Wilson, R. N.,	Guilford College.
Winston, Geo. T.,	West Raleigh.
Williams, C. B.,	Raleigh.
Wheeler, A. S.,	Chapel Hill.

VOL. XX NOV. 1904 NO. 3

JOURNAL

OF THE

Elisha Mitchell Scientific Society

(Official Publication of the N. C. Academy of Science)

ISSUED QUARTERLY

CHAPEL HILL, N. C., U. S. A.

TO BE ENTERED AT THE POSTOFFICE AS SECOND CLASS MATTER

Elisha Mitchell Scientific Society.

CONTENTS.

Journal of the Elisha Mitchell Scientific Society—Quarterly. Price $2.00 per year; single numbers 50 cents. Most numbers of former volumes can be supplied. Direct all correspondence to the Editors, at University of North Carolina, Chapel Hill, N. C.

JOURNAL

OF THE

ELISHA MITCHELL SCIENTIFIC SOCIETY

(Organ of the North Carolina Academy of Science)

VOL. XX. NOV. 1904

PROCEEDINGS OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY.

OCTOBER 13, 1903.

Professor *Collier Cobb*, President, in the chair.

The following papers were presented :

The Use of the Vector Diagram in Electrical Engineering. *J. E. Latta.*

Tanning. *Charles Baskerville.*

A New Indicator. *E. V. Howell* and *A. S. Wheeler.*

The Influence of the Spermatozoon on the Larval Development of the Sea Urchin. *H. V. Wilson.*

CHARLES BASKERVILLE,
Recording Secretary.

BUSINESS MEETING, OCTOBER 13, 1903.

The following were elected as members : From Chapel Hill—Wm. McK. Marriott, L. B. Lockhart, W. H. Oldham, W. A. Whitaker, George MacNider, W. W. Eagles, Greene Berkeley, F. H. Gregory ; from Raleigh—Joseph Graham, M. D.

The following arrangement with the North Carolina Academy of Science was approved: The Elisha Mitchell Journal assumes the publication of the proceedings of the Academy in its initial number; the Journal is to be enlarged to 200 pages and to be issued quarterly; the Academy is to

[Issued 20th November.]

pay annually the sum of one hundred dollars towards the support of the Journal; the editing and issuing of the Journal is to remain in the hands of the Elisha Mitchell Society; the Journal is to retain its name, but upon the title cover will appear in small letters, "Official Publication of the North Carolina Academy of Science;" each member of the Academy is to receive gratis one copy of the Journal; associate members are to receive only the first number of the volume following the meeting at which the subscriber was an associate.

An invitation was extended to the North Carolina Academy of Science to hold its next annual meeting at the University November 12th and 13th. Professors Gore, Coker and Wheeler were appointed a committee of arrangements.

The following officers were elected for the ensuing year:

President, *Charles Baskerville.*

Vice-President, *J. E. Latta.*

Recording Secretary, *A. S. Wheeler.*

CHARLES BASKERVILLE,
Recording Secretary.

JANUARY 12, 1904.

Mr. *J. E. Latta*, Vice-President, in the chair.

The following paper was presented:

Elements, Verified and Unverified. *Charles Baskerville.*

A. S. WHEELER,
Recording Secretary.

FEBRUARY 9, 1904.

Professor *Charles Baskerville*, President, in the chair.

The following papers were presented:

Mendel's Law of Heredity. *W. C. Coker.*

Incomplete Division in Vertebrate Animals. *H. V. Wilson.*

Composition of Coastal Plain Sands in Relation to Distance from Existing Shore Lines. *Collier Cobb.*

A. S. WHEELER,
Recording Secretary.

MARCH 8, 1904.

Professor *Charles Baskerville*, President, in the chair.

The following papers were presented:

Mercerisation. *A. S. Wheeler.*

The Work of the Digestive Glands. *I. H. Manning.*

Kunzite, the New Gem; Its Unique Properties (with demonstrations). *Charles Baskerville.*

A. S. WHEELER,
Recording Secretary.

APRIL 12, 1904.

Professor *Charles Baskerville*, President, in the chair.

The following papers were presented:

The World's Production and Consumption of Coal. *C. L. Raper.*

Grafting in Vertebrate Embryos. *H. V. Wilson.*

Protozoa in Smallpox. *R. H. Whitehead.*

A. S. WHEELER,
Recording Secretary.

BUSINESS MEETING, SEPTEMBER 12, 1904.

Professor *F. P. Venable*, Corresponding Secretary, in the chair.

The following officers were elected for the ensuing year:

President, *Wm. Cain.*

Vice-President, *J. E. Mills.*

Corresponding Secretary, *F. P. Venable.*

Recording Secretary, *A. S. Wheeler.*

Editorial Committee on the Journal, *W. C. Coker, J. E. Latta, Archibald Henderson.*

A. S. WHEELER,
Recording Secretary.

SCIENCE AND THE PEOPLE.*

CHAS. BASKERVILLE.

Opportunities beget responsibilities. On such an occasion as this, he who has been honored with the opportunity is tempted to address you upon a specialized subject to which he has given years of thought and interest, but the opportunity carries with it corresponding responsibilities beyond the narrow bounds of one's limited investigations. The audience is composed in part of the general public, which is more or less informed, or misinformed through no self-fault, as to the general trend of scientific thought and movement; in part of students, some enwrapt with the beauty and majesty of ancient art and philosophy, others versed in the history of science and conversant with its latest conceptions; in part, my hearers are specialists in the varied branches of science, so I feel much like Moleschott in his address at the reopening of the University of Rome, when he found himself "in the face of an audience whom he had nothing to teach, but from whom he had much to learn."

The groundwork of science may be thrown into three divisions: (1) laborers who work; (2) tools they must employ; and (3) that which constitutes the fields of their labors.

In the world we know there is such a thing as progress; that civilization is dependent upon something capable of increase, evidently knowledge. Although, as Schiller has said, "Knowledge is to one a goddess, to another an excellent cow." yet the momentum of progress is largely, if not altogether, given by science.

Variation in social conditions have caused variations in

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* **Retiring address** of the president of the North Carolina Academy of Science. Wake Forest College, May 13, 1904. Science, *20*; 266–273. 1904.

human standards of morality, but through all the ages morality has actually been a stationary thing. Different ages have known mighty things in literature and art, but each was the individual outcome of the pen or the brush of the genius, who bequeathed a heritage of his own labors as a stimulus to others; but the mastership passed with him. Not so with science; for, as Whewell has said, "It is not a collection of miscellaneous, uncorrected, unarranged knowledge that can be considered as constituting science."

Different ages have known mighty things in science, sometimes as the outcome of a genius, but equally as often the consequence of talent building upon that which was learned before. So, never was one more mistaken than President Woodrow Wilson when he stated that science breaks with the past.

In order to appreciate the spirit of modern science, we must take a hurried glance at the motives prompting the older workers and consider their environment. We are aware, in the historical development of things, that all present knowledge arose from a chaotic state enveloping itself in mystery. This was due to the empirical means of observation, superstition attending any inquiry into the why of things, hampering circumscriptions of religions, primitive and more recent, and lack of means of communication. The wise man, exercising a little common sense, wrought cures wonderful in those dark times, many simple for the youngest practitioner of today. While, doubtless, some were prompted by an earnest desire to do good, many were actuated by greed of power and gain, even as today. Fearful of their loss once secured, they often sought to hide their own shortcomings and take advantage of the universal ignorance by their mysticism. These were not the sole motives of all workers, however. The spirit of inquiry has ever been present with mankind. For

"Ignorance is the curse of God,
Knowledge the wings wherewith we fly to heaven."

Although, three hundred years before Christ, the living and dead were dissected at the Alexandrian school, it was not until the fifteenth century that the popes overcame popular prejudice about the sancity of the dead body and issued edicts permitting dissection. The following century, Vesalius arose, and then Harvey discovered the circulation of the blood. Greek philosophers first endeavored to place science upon a purely rational basis and they were accused of impiety. To be sure, it may be said that such impeachments have not ceased to sound for over two thousand years and cost the lives of many good and noble men. The church considered Galileo and similar workers as rank heretics. Certain scientific endeavors were tolerated, and the knowledge gained confined within monastic walls. In the hearts of some was that yearning to make known the truths they had dreamed; and monks like Roger Bacon, Basil Valentine and Berthold Schwartz put forth writings so mysterious as to be incomprehensible to many, but having hidden realities not previously made known.

Science was centuries acquiring its natural voice. In the dark ages only a small band of learned folk made itself known, yet the voice of Kepler, saying "The scientist's highest privilege is to know the mind and think the thougts of God," sounded three centuries ago, has echoed with increasing reverberations to our own time. Science, harassed by ding-dong, useless and unnecessary authority, was driven into rigid pious paths. As the very spirit of science is inquiry, it lives upon liberty and would not be bound by authoritative misconceptions. It is not strange, then, that in a democracy of thought permitting the widest range of opinions men should have been borne away to the other extreme, and such catching expression as "every one for himself and no god for any one," became prevalent. "Scientific arrogance" was a pet expression of theologians who trespassed none the less than had the scientists. "The abuse heaped upon Newton for substituting blind gravitation for an intelligible Deity" that John Fiske tells about, was nothing in comparison with the subsequent treatment of geologists by theologians for disturbing the

Bibical chronology. The highest teaching of scientific verities is the absolute necessity for the existence of God. In fact, one need not go far for a chemical confirmation of the resurrection, as death is but a phase of our continual internal change; "so when this corruptible shall have put on incorruption and this mortal shall have put on immortality," our natural body sown in dishonor and weakness, shall be raised a spiritual body, clothed in glory and power; "and as we have borne the image of the earthly, we shall also bear the image of the heavenly." It is only in the most modern times that the scientific spirit, which looks to the relative and temporarily excludes the absolute, has begun to be fully applied and extended to ideas of every order.

I am by no means unmindful of the dogmatism of science at times, for it may be recalled that Daguerre was actually temporarily incarcerated in an asylum because he maintained he could transfer his likeness to a tin plate; Franklin's paper on lightning conductors was laughed at and not published by the Royal Society; and Galvani was attacked by his colleagues, designated a know-nothing, and called "the frog's dancing master." The Count de Gasparin even wrote in the *Journal des Debats*, "Take care; the representation of the exact sciences are on their way to become the inquisitors of our days."

Science does not pretend to say the last word in regard to the universe, but it builds hypotheses upon observed and unobserved facts which are altered or cast aside in the light of all new correctly obtained facts. It is ever ready to declare the increasing uncertainty of many delightful and ideal conceits, which is not to be taken as vacillation, but as evolution, growth. The late distinguished Lord Playfair at the Aberdeen meeting of the British Association said: "The changing theories which the world despises are the leaves of the tree of science drawing nutriment to the parent stems, and enabling it to put forth new branches and to produce fruit; and though the leaves fall and decay, the very products of decay nourish the root of the tree and reappear in the new leaves or theories which succeed." With this spirit, it will not hesitate to attack any of our pet scientific, sociological or theological dogmas, which are frail as all human system must be. These attacks are without venom, however, for "Science * * * requires for its satisfactory prosecution the employment of our very noblest powers, and it is by them alone that we can hope to attain a knowledge of the most supreme and ultimate truths which our intellectual faculties have the power to apprehend."—(Mivart.)

Although Gough remarked to Dalton, "The human mind is naturally partial to its own conceptions and frequently condescends to practise a little self-delusion when obliged by the force of facts and argument to abandon a favorite notion," the supreme lesson in the history of science, most marked in our own time, is the pursuit of truth. Much time has been spent in defining *art* and casting that which did not fit a pet definition into a rubbish box called *science*, or "natural knowledge" as a member of the Royal Society was pleased to term it. Many of those insisting upon such a classification are not without reason, for have not certain phylogenetics promulgated on the flimsiest excuse some *pan mixia*, as Weisman's germ-plasm theory and then easily remembering the conclusions, but forgetful of the evidence, maintained that it was a law? Or has not a Tesla over magnanimously taken the public into his confidential conversations with the inhabitants of Mars?

It has been fashionable in years gone by to say that poetry and truth were antagonistic. Coleridge and Poe, I think, insisted that science and poetry were irreconcilable. Incongruous statements, as when Shakespeare speaks of toothache "as humor or a worm", doubtless gave rise to such thoughts. The Avon poet put it according to the scientific teachings of his time. Civilization and methods of interpreting the truth change and progress, but truth itself is eternal. Science will no more replace literature than can a geometric diagram be substituted for a landscape painting.

Science, to be sure, is destructive of conventions. Freedom is the breath of science, and the unshackled movement of boundless human curiosity must effect literature. Men of science look not pleasantly upon their scavenging camp followers, who, riotous in thought, indulge in a license of speech which provokes quite justly those who conscientiously differ from them, and unfortunately inculcates ideas in those unable to winnow the chaff from the grain.

Thus it may be seen that modern science makes for purity and genuineness. There is nothing more abhorrent to a man of science than the pretenses of a scientific mountebank. This elevation is dual in its effect, general and local. As an evidence of the former there have resulted ameliorated conditions of society by protecting food from harmful adulterations, improved sanitation, better and more reasonable treatment for diseases, general distribution of the products of wealth among all civilized peoples, and in many other ways too numerous to mention. A reader after Count Tolstoy and his "recognition of the bankruptcy of experimental science," can not but be impressed with his earnestness, and yet feel that he looks only very close at home when he writes: "The men of science of our time think and speak and the crowds follow them, while at the same time there was never a period or a people among whom science in its complete significance stood on so low a level as our science to-day. One part of it, that which should study what makes life of man good and happy, is occupied in justifying the existing evil conditions, while another part spends its time solving questions of idle curiosity." He does not apparently realize that science promotes a certain continuity of ideas, as well as the intellectual and moral education of the nations.

"There exist, indeed and always will exist, many deplorable things, much suffering, and much wickedness in the world; but it is to the credit of science that, instead of lulling mortals with the feeling of their powerlessness into passivity of resignation, it has urged them to react against destiny, and has taught them the sure way by which they can diminish the sum of woe and injustice, and increase their happiness and that of their fellows. It has not accomplished this by means of verbal exhortation or *a priori* reasoning, but by virtue of processes and words really efficacious, because they are acquired from the study of conditions of existence and the causes of evil."

Further, as the editor of *The Popular Science Monthly* has said:

"The advance of science is evidenced in numberless ways, but our weightiest proof of it is found in the gradual acceptance of enlarged in place of narrower views of the subject. New discoveries are important; the widening of the ranges of research is important; the extension of generalization and better organization of positive knowledge are important; but more inportant still is the growing general recognition that science is the grand agency in modern times for reshaping the common opinions of the community."

The local elevating effect of work in pure science is the taking a man away from the sordid things of the world, and

"No life can be pure in its purpose, and strong in its strife,
And all life not be purer and stronger thereby."

By this I would not be understood as placing him who works only in pure science on a pedestal, or intimate that he is superior to the other who makes a practical outcome of his scientific work the main object. I am well aware of the eloquent statements about this being an industrial age and the duty of young men te seek a technological education. Far be it from my purpose to exhibit the least antagonism to the generalspirit of such appeals, for I endeavor to teach much of the same thing, but in it all and with it all, I would urge that the pure science be either kept ahead or abreast of commercial progress. Neither the pure nor the practical deserves to be developed alone. They are inter-dependent and have always grown together. The pure research has been utilized later in practise. Industrial demands have stimulated investigation. Illustrations abound. The destiny of nations has been changed by scientific investigations prompted either by search for research sake or by a commercial call. The history of indigo reads like a novel, for chemists have accomplished the task, not of producing artificial indigo, but the genuine indigo by artificial means. The modern spirit of pure science thus elevates man's ideals and that of the applied adds to his comfort, pleasure and happiness.

In advocating Du Bois Reymond's "Hellenism" or the love of humanistic and scientific culture for its own sake, apart from all considerations of profit and advantage, I would not be understood as

> "Nourishing a youth sublime
> With the fairy tales of science."

While I maintain that the dollar should not be the guiding star, there is no objection to dwelling upon the practical value of science; for, as Huxley has said: "it has become obvious that the interests of science and industry are identical; that science can not make a step forward without, sooner or later, opening up new channels for industry; and, on the other hand, that every advance of industry facilitates those experimental investigations upon which growth of science depends."

It is well understood by those who have knowledge of the problem that the first line of defense in industrial warfare is the educational centers. We are a great industrious and prosperous nation. Prosperity is the possession "of enlarging opportunities to secure the gratification of our material, intellectual, social and spiritual wants."

In the foregoing I have endeavored to show that science is an evolution. In the past, to be sure, at times it has marched with crippled steps, at present it is gripped into the vitals of nations. The modern spirit of science towards religion is sane and healthy; towards literature it leans in offering themes alive and seeking graceful modes for its expression; it fosters and grows with industry, so "to choke the fountains of science is to dry the source of our prosperity."

The progress of science among us very largely depends, as Draper has said, on two elements; first, our educational establishments: and second, our scientific societies.

School men within the past decade have learned that it is proper to send the whole boy to school and little by little science has come into the curriculum. There is room for much more sane science and its more widespread teaching, and it should be better taught. Let us teachers then have more to do with pushing the proper recognition of science before the attention of school boards, insisting upon adequate compensation, and let us have men and women ready-equipped for the work. Pardon a personal illustration. I use it solely because I know whereof I speak. Every year there go out from our laboratory at the university a dozen or more graduates who, with rare exceptions, and they are mainly my own assistants, are offered position in other states. We can change this, and I take it as one of the things this academy may hold out for its accomplishments. How?

We teachers can and must get out and see the schools, confer with the boards, speak to the people, in short, see that wholesome works in science are placed in the libraries, tell of common sense science, hygiene, assist the great work and create like things to the farmers' institutes, popularize science. There is "no discredit in popularizing science," as Mendenhall said, "that popularizing what is not science is the thing that is to be shunned and avoided."

This brings to our immediate attention the instructors in the various institutions that are making the teachers, making the preachers, the lawyers, the doctors, business men and the citizens. Boards of trustees must be made to clearly understand that time and equipment for these things must be had; boards of trustees must be made to understand that the best teachers are those who contribute something to that sub ject they would have better known and appreciated; boards of trustees must be impressed with the fact that with our present arrangements, most researchers must steal the time necessary from rest, sleep, social concernments and family pleasures and that is not right, it is not just to make them mere teaching machines.

There is no question whatever but that many of the teachers in our institutions do the treadmill. All of this can not with justice be laid at the doors of our honorable governing bodies, however, for teachers are vain as other mortals. Some insert in catalogues a vast array of special courses, which either are solely for show, or, if they be given of necessity, can not be with that fresh vigor which should characterise instruction. The man who does that voluntarily loves not really his science. It is far wiser to offer a few courses, give them well and contribute a bit, even a mite, to the sum of knowledge. I do not know but that the late Professor Rowland was a bit severe, yet I wish to quote from an address of his on a "Plea for Pure Science". Some children may be coaxed, others require whipping.

"It is useless to attempt to advance science until one has mastered the science; he must step to the front before his blows can tell in the strife. Furthermore, I do not believe anybody can be thorough in any department of science, without wishing to advance it. In the study of what is known, in the reading of the scientific journals, and the discussion therein contained of the current scientific questions, one would obtain an impulse to work, even though it did not before exist. And the same spirit which prompted him to seek what was already known, would make him wish to known the unknown. And I may say that I never met a case of thorough knowledge in my own science, except in the case of well-known investigators. I have met men who talked well, and I have sometimes asked myself why they did not do something; but further knowledge of their character has shown me the superficiality of their knowledge. I am no longer a believer in men who could do something if they would, or would do something if they had a chance. They are imposters. If the spirit is there, it will show itself in spite of circumstances."

Your speaker wishes to plead with his southern colleagues for greater activity in research. Many have told me they had no appliances. Liebig had none at first and later bought most or that which he had from his slender stipend; Priestley utilized a lens and sun's heat and discovered oxygen, Wöhler distilled potassium, using a bent gun barrel as a condenser in in Berzelius's laboratory. Where there's a will, there's a way. There is much unknown, so much to learn, and, as Victor Meyer has said, there is "the gaining of gold from rubbish."

Yes, our equipment is meager; poorer than it ought to be for states now far richer than ever in their history; grown rich, too, as a result of the progress of industries. Science sowed the seed of the present prosperity and it is worthy of rememberance, thanks, reward. And these will come. In a measure, they have come. Every scientific man in the state takes pride in the growth of the new biological building at this institution, beneficent generosity of a prominent trustee at Trinity college equipping the physics department, the conduct of the soil survey under the direction of the Department of Agriculture, the Beaufort laboratory, etc.

The importance of promoting science as the duty of the states was well known to the ancients, especially the Greeks and Arabs. The Prince Consort, in an address before the British Association in 1859, made the following statement:

> "We may be justified in hoping * * * that the legislature and the state will more and more recognise the claims of science to their attention; so that it may no longer require the begging-box, but speak to the state like a favored child to its parents; sure of his parental solicitude for its welfare; that the state will recognize in science one of its elements of strength and prosperity; to foster which the clearest dictates of self-interest demand."

The endowment of any laboratory in any institution of the state but helps the others. There is no such thing as competition in doing good. The blanket of ignorance may be lifted a bit higher here than there, but each lifts and gives the fresh air of knowledge to those smothering beneath.

So, my friends, in fulfilling the responsibilities begotten of the honor, allow me in closing to give my conception of the destiny of this academy.

Man depends much for his happiness upon the sympathy of those around him; "it is rare to one with courage to pursue his own ideals in spite of his surroundings." So science thrives best where societies exist for its advancement. Science speaks a universal language and knows no geographical, political or social boundaries, otherwise Humphrey Davy would never have been so cordially entertained by his French colleagues when the shores of England and France bristled with bayonets in bloody antagonism. Then let us thank God for the brotherhood of science, for the science, the spirit of modern science, is at war with war. The right spirit of science is that of patient inquiry; of longing for the truth, cost what it may in brain power, energy, money or self denial; it is the spirit of cooperation as wide as the needs of man; of constructive effort through slow accretion by many years. "The touch of science makes the whole world kin."

MOLECULAR ATTRACTION.*

(SECOND PAPER.)

BY J. E. MILLS.

REVIEW OF THE THEORY.

This paper presents additional evidence tending to show that the attraction between molecules varies inversely as the square of their distance apart and does not vary with the temperature. Considering the attraction as a property belonging to each molecule, or to be more exact, a mutual property of each pair of molecules, it must vary as the mass, large numbers of similar molecules being here considered. Briefly therefore this paper is an attempt to show that the *law of gravitation* holds, not only between masses, but between the molecules of a substance, and that this law is alone sufficient to account for the phenomena of the internal latent heat of vaporization.

The assumptions upon which the present work is based are stated in the original paper,[1] and it would not be necessary here specifically to call attention to them were it not for the fact that certain reviews have overlooked the significance of the preliminary statements to that paper. We may say that the steps leading up to the present work are briefly:—

1. The kinetic theory of gases and van 't Hoff's application of the gas law PV = RT to solutions.

2. The conclusion from the above theories and related work that the average translational energy of gaseous and liquid molecules must at the same temperature be equal.

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* Reprinted from the Journal of Physical Chemistry, Vol. 8, No. 6, June, pp. 383–415 (1904).

[1] Jour. Phys. Chem. 6, 209 (1902).

2. The belief based on the study of the specific heat of gases, that the *total* energy of a gaseous molecule, exclusive of the energy which holds the molecule together and of extraneous forces, is proportional to the translational energy.

4. The inference, for it is somewhat more than a mere assumption, the causes for 3 being considered, that the *total* energy of a molecule of a liquid would similarly be found to be proportional to its translational energy.

These four preliminary steps may be summed up by the statement that the total energy *per se* of a molecule must be the same in the liquid as in the gaseous state, the temperature being the same. If at a given temperature a given weight of gas represents more energy than the same weight of the substance as a liquid; the extra energy of the gas must be energy of position only (assuming no intramolecular change).

We made no attempt in the former paper, and we make none in this, to prove the last statement above, or to give the evidence for it. To do so even cursorily would require a discussion of the kinetic theory of gases, their specific heats more particularly, and the modern theories of solution. The statement is here made only as the belief of the author upon which the present work is based. Many citations of closely related belief might be given. Oswald[1] gives a clear and succinct statement of 1 and 2. O. E. Meyer[2] shows the grounds for 3. The author has published[3] the study which led him to conclude that 4 was a reasonable supposition. So long ago as 1885, Ramsay and Young made practically the same statement.[4]

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[1] Solutions pp. 147, 148.

[2] Kinetic Theory of Gases, p. 117.

[3] Journal of the Elisha Mitchell Scientific Society, Vol. 18 (1902).

[4] Phil. Trans. **1886A**, Evaporation and Dissociation, p. 72, Section 4; *c* and *d* of that section not being necessary under the limitation imposed above that there should be no intramolecular change, and *e* and the footnote being unnecessary in the light of the later work of van 't Hoff.

Expressing the above belief in a different form, we may say that the energy necessary to change a liquid into a gas must then be spent solely in overcoming the external pressure and in altering the distance apart of the molecules. (Unless the molecule breaks apart also or nears the point of disruption.)

Denoting the energy spent in overcoming the external pressure by E_1, this energy can be calculated from the equation,

$$[1] \qquad E_1 = 0.0_4 31833\ P(V - v) \text{ cals.},$$

where the unit calorie is from 15° to 16° C, P is the pressure in millimeters of mercury, V and v are the volumes before and after expansion. To obtain the constant, $0.0_4 31833$, we used the values: density of mercury, 13.5956; Rowland's value of the therm, corrected by Day, at 15° to 16° C, 41880000 ergs, as unit; and gravity taken as 980.5966.

Denoting the total latent heat by L, we have $L - E_1$ as the energy spent in overcoming the molecular attraction at any particular temperature.

On the further assumption:

5. That the molecular attraction varies inversely as the square of the distance apart of the molecules, the equation 7 (p. 212) of the original paper was derived, which equation readily takes the more convenient form,

$$[2] \qquad \frac{L - E_1}{\sqrt[3]{d} - \sqrt[3]{D}} = \text{constant},$$

for any particular substance, where $L - E_1$ is the internal latent heat of vaporization, and d and D are the densities of liquid and vapor at any particular temperature.

With regard to this equation, we will here say that it was designed to test the assumption advanced in 5. Had it failed to produce a constant or some function of the temperature, the author hoped to substitute 5 by some other distance function of the attraction, obtain the formula similarly, and thus repeat until the correct assumption was made.

As to the mathematics by which it was derived, the vagaries of a particular molecule cannot of course be followed. But in considering energy relations we commit no error by considering the average molecule as was done. The formula should therefore hold strictly true provided:—

(*a*) The molecules are evenly distributed.
(*b*) The number of molecules does not change.
(*c*) No energy is spent in intramolecular work.
(*d*) The attraction does not vary with the temperature.

Or, we might sum up *a*, *b*, *c*, and *d*, by saying that formula 2 should hold, provided we are dealing with a stable chemical compound whose molecules are not associated.

The first paper tested the formula so far as the direct measurements of latent heat and the related data permitted. The agreement appeared to be much too close to be the result of accident, but where variations in the data as given by different observers amounted often to five and ten per cent., any close agreement was impossible. It being impracticable to make direct measurements of the latent heat at widely different temperatures, attention was called to the measurements of Ramsay and Young and of Dr. Young. These measurements give the vapor pressure and density of liquid and vapor, at corresponding temperatures over a wide range of temperature for thirty-one substances. The present paper deals with twenty-one of these substances, the calculations for the ten esters being not yet completed.

THE MEASUREMENTS.

The complete measurements used are given in the appended tables.

The few exceptions to the following general statements are noted below.

(*a*) The vapor pressure, density of the liquid, and density of the vapor, are from the measurements, references given below, by Professors Ramsay and Young, or Young.

(*b*) The vapor pressures from Biot's formula were used in preference to the observed values.

(*c*) Where calculated the density of the vapor was obtained from the formula,

$$D = 0.0_4 16016 \frac{Pm}{T}, \qquad [3]$$

where P is the pressure in millimeters of mercury, m is the molecular weight, oxygen equal to 16 as the standard, and T is the absolute temperature. The constant $0.0_4 16016$ was obtained by the use of the values $0.0_4 89873$ for the density of hydrogen at 0° C, 760 mm. pressure, latitude 45° and sea level, and 0° C = 273° absolute.

(*d*) The densities of the vapor given are often carried one place further than the accuracy of the measurements would warrant. This was because the density of the vapor was not always given directly in the original paper, and in the necessary transposition the additional figure of the calculation was retained.

(*e*) Making use of the well-known thermodynamic equation,

$$L = \frac{\delta P}{\delta T} \frac{T}{J} (V - v), \qquad [4]$$

the latent heat of vaporization for methyl, ethyl and propyl alcohols, acetic acid, and ether, were calculated and given in the original papers, where the method in detail may be obtained. The latent heat for water, 0° to 230° C, is from Regnault. The latent heat for benzene, 0° to 270° C, is from Tsuruta,[1] using measurements of Young.

(*f*) In all other cases the latent heats were calculated by the author, the following method being used. Biot's general formula for the vapor pressure,

$$\log P = a + b\alpha^t + c\beta^t, \qquad [5]$$

has been found with properly chosen constants accurately to represent the vapor pressure, Differentiating and changing base of the logarithms from natural to Naperian we get:

$$\frac{\delta P}{\delta t} = \frac{P}{m^2} (b \log \alpha\alpha^t + c \log \beta\beta^t) \qquad [6]$$

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[1] Phys. Rev. 10, 2 (1900).

where $m = 0.434294$. Substituting this value of $\frac{\delta P}{\delta T}$ in equation 4, we get:

$$[7] \qquad L = 5.3019 \frac{P(V-v)T}{J}(b \log \alpha\alpha^t + c \log \beta\beta^t);$$

and using values for P and J already adopted (p. 82), we have finally:

$$[8] \quad L = 0.0_3168775\, P.\Delta v.T\,(b \log \alpha\alpha^t + c \log \beta\beta^t), \text{ cals.; or}$$

$$[9] \qquad L = \frac{P.\Delta v.T}{10^6} A \text{ cals., if,}$$

$$[10] \qquad A = 168.775\,(b \log \alpha\alpha^t + c \log \beta\beta^t).$$

In this form the calculation of the latent heat is not only theoretically correct, but is much shortened in comparison with the usually adopted methods. The values for A were obtained from the constants for Biot's formula given in the original papers, and the equations thus derived for each substance are given below under that substance.

(*g*) All calculations in this paper were checked and every effort was made to make the calculations as accurate as the data from which they were derived.

Ether. See Table 2. Data from Phil. Trans. 1887A, p. 57; except density of liquid at 10°, 20° and 30° C, where the values are from Oudemans. Molecular weight used 74.08.

Di-isopropyl. See Table 3. Data from Jour. Chem. Soc. 1900, p. 1126, except vapor pressure at 216° and 225° C (calculated from Biot's formula); and vapor density at 0° C which is theoretical. Molecular weight used, 86.112. For calculation of the latent heat,

$$A = \text{antilog}\,(\bar{1}.572552 - 0.00020800t) + \text{antilog}\,(0.1268648 - 0.00466932t),$$

where $t = t°\,C + 10$.

Di-isobutyl. See Table 4. Data from Jour. Chem. Soc.

1900, p. 1126, except vapor pressure at 274° C (calculated from Biot's formula); and vapor density at 0° C which is theoretical. Molecular weight used, 114.144. For calculation of the latent heat,

$$A = \text{antilog}\,(\bar{1}.1739925 + 0.00104426t) + \text{antilog}\,(0.2271234 - 0.00380225t),$$

where $t = t^\circ\,\mathrm{C} - 10$.

Isopentane. See Table 5. Data from Proc. Phys. Soc. 1895, p. 602; except vapor density at 0° C which is theoretical. Molecular weight used, 72.10. For calculation of the latent heat we have,

$$A = \text{antilog}\,(\bar{1}.6310169 - 0.00031549t) + \text{antilog}\,(0.1373762 - 0.00515903t),$$

where $t = t^\circ\,\mathrm{C} + 30$.

Normal Pentane. See Table 6. Data from Jour. Chem. Soc. 21, 1897, p. 446; except vapor density at 0° C which is theoretical. Molecular weight used is 72.10. For calculation of the latent heat, we have,

$$A = \text{antilog}\,(\bar{1}.7496468 - 0.00073363t) + \text{antilog}\,(0.0668185 - 0.00551392t),$$

where $t = t^\circ\,\mathrm{C} + 20$.

Normal Hexane. See Table 7. Data from Jour. Chem. Soc. 1895, p. 1071; except vapor density at 0° C which is theoretical. Molecular weight used is 86.11. For calculating the latent heat, we have,

$$A = \text{antilog}\,(\bar{1}.3604438 + 0.00042355t) + \text{antilog}\,(0.2029359 - 0.00411255t),$$

where $t = t^\circ\,\mathrm{C} + 10$.

Normal Heptane. See Table 8. Data from Jour. Chem. Soc. 74, 1898; except vapor density at 0° C which is theoretical, and vapor pressure at 266° and 266.5° C which is calculated from Biot's formula. The molecular weight used is 100.13. For calculation of the latent heat, we have.

$$A = \text{antilog}\,(\bar{1}.3407071 + 0.00053408t) + \text{antilog}\,(0.2342860 - 0.00403623t),$$

where $t = t°$ C.

Normal Octane. See Table 9. Data from Jour. Chem. Soc. 1900, p. 1145; except vapor density at 0° C which is theoretical. The molecular weight used is 114.144. For calculation of the latent heat, we have,

$$A = \text{antilog}\,(\bar{1}.3927781 + 0.000342913t) + \text{antilog}\,(0.2497609 - 0.004006534t),$$

where $t = t° \text{ C} - 10$.

Benzene. See Table 10. Data from Jour. Chem. Soc. 1889, p. 486, and 1891, p. 125; except density of vapor at 0° C which is theoretical. Molecular weight used is 78.05. Latent heats were calculated by Tsuruta (Phys. Rev., 1900, p. 116), except at 0° C, where the value found by Griffiths and Marshall is used, and at 280° C where the calculation was made by the author.

Hexamethylene. See Table 11. Data from Jour. Chem. Soc. 1899, p. 873; except vapor density at 0° C which is theoretical. Molecular weight used is 84.096. For calculation of the latent heat, we have,

$$A = \text{antilog}\,(\bar{1}.2956115 + 0.00049715t) + \text{antilog}\,(0.1878242 - 0.00391252t),$$

where $t = t°$ C.

Fluo-benzene. See Table 12. Data from Jour. Chem. Soc. 1889, p. 486, and 1891, p, 125; except the vapor density at 0° C which was calculated. Molecular weight used is 96.09. For calculation of the latent heat, we have,

$$A = \text{antilog}\,(\bar{1}.13157974 + 0.000942654t) + \text{antilog}\,(0.2224140 - 0.00363024t),$$

where $t = t°$ C.

Chlor-benzene. See Table 13. Data from Jour. Chem. Soc. 1889, p. 486, and 1891, p. 125; except vapor density at 0° C which is theoretical. The molecular weight used is 112.5. For calculating the latent heat, we have,

$$A = \text{antilog}\,(\bar{1}.2268791 + 0.00075845t) + \text{antilog}\,(0.1846519 - 0.00359227t),$$

where $t = t°\,C - 30$.

Iodo-benzene. See Table 14. Data from Jour. Chem. Soc. 1889, p. 486, and 1891 p. 125; except vapor density at 30° and 100° C which is theoretical. Molecular weight used was 203.9. For calculating the latent heat, we have,

$$A = 0.09891873 \left\{ \text{antilog}\,0.001421982t + \text{antilog}\,(1.28759778 - 0.00324574t) \right\},$$

where $t = t°\,C - 30$, a form of the equation less convenient for calculation than the one usually adopted.

Brom-benzene. See Table 15. Data from Jour. Chem. Soc. 1889, p. 486, and 1891, p. 125; except vapor density at 30° and 100° C which is theoretical. Molecular weight used was 157.0. For calculation of the latent heat, we have,

$$A = \text{antilog}\,(\bar{1}.8373717 - 0.00095092t) + \text{antilog}\,0.0763464 - 0.00489465t),$$

where $t = t°\,C - 30$.

Carbon Tetrachloride. See Table 16. Data from Jour. Chem. Soc. 1891, p. 911; except vapor density at 0° C which is theoretical. Molecular weight used was 153.8. For calculation of the latent heat, we have,

$$A = 0.2358 \left\{ \text{antilog}\,0.00026855t + \text{antilog}\,(0.7970507 - 0.00402434t) \right\},$$

where $t = t°\,C$, a less satisfactory form of the equation than the one usually adopted.

Stannic Chloride. See Table 19. Data from Jour. Chem. Soc. 1891, p. 911; except density of the vapor at 0° which is theoretical, the molecular weight used being 260.8. For calculating the latent heat, we have,

$$A = \text{antilog}\ (\bar{1}.3282379 + 0.00026212t) + \text{antilog}\ (0.2481708 - 0.00368282t)$$

where $t = t°$ C.

Water. See Table 18. See Phil. Trans. 1892, p. 107. Vapor pressures, 0° to 100° C, are Broch's calculations from Regnault's measurements, and other values are from Ramsay and Young. Density of the liquid, 0° to 100° C are from values in Landolt and Bornstein's tables, p. 39, and 100° to 270° C are from Ramsay and Young. Density of vapor, 0° to 210° C are as given by Ramsay and Young from Regnault's heats of vaporization, and 230° to 270° are "recalculated" values from their own measurements. Latent heats, 0° to 230° C are from Regnault, and 240° to 270° C were calculated by the author from the formula,

$$A = \text{antilog}\ (0.1416514 - 0.005950708t) + \text{antilog}\ (0.13884017 - 0.001656138t)$$

where $t = t°\ C + 20$, the constants used for Biot's formula being given by Regnault.

Methyl Alcohol. See Table 19. Data from Phil. Trans. 1887A, p. 313; except density of liquid at 0° C from Dittmar and Fawsitt, and at 10° C average value of 0° and 20°. Inadvertently the observed pressures were used for the calculation of E_1, but the difference thus made is never more than 0.1 to 0.2 calorie, and the error thus introduced into the constant of equation 2 could never exceed one-tenth of one per cent.

Ethyl Alcohol. See Table 20. Data from Phil. Trans. 1886A, p. 123; except vapor pressure at 241°, 242°, and 242.5° C (calculated from Biot's formula); density of liquid 0° to 30° and at 100° Mendelejeff, 40° to 80° from Kopp's formula, and at 90° C estimated value.

Propyl Alcohol. See Table 21. Data from Phil. Trans. 1889A, p. 137. Observed vapor pressures were used to calculate E_1. Density at 0° C is theoretical, the molecular weight used being 60.06.

Acetic Acid. See Table 22. Data from Jour. Chem. Soc. 49, 1886, p. 790, and in 1891. Vol. 59. p. 903, preference being given in all cases to the later measurements. For calculating the latent heat, we have,

$$A = \text{antilog}\ (\bar{1}.9257964 - 0.00149898t) + \text{antilog}\ (\bar{1}.1390566 - 0.0130424t),$$

where $t = t° \text{ C} - 120$.

APPLICATION OF THE THEORY.

For details of the calculations involved the appended tables, 2 to 22, must be consulted. A summary of the results obtained for the constant by the use of the equation $\frac{L - E_1}{\sqrt[3]{d} - \sqrt[3]{D}} = \text{constant}$, is given below in Table 1. Certain mean values of this constant somewhat arbitrarily chosen are given at the top of each column. All results not in agreement with this mean value of the constant by as much as two per cent. are in italics.

Since from 0° C to within 10° of the critical temperature eleven of the substances show altogether, out of two hundred and seventeen observations, only two divergences greater than two per cent. from the average values, it is clearly evident that the relation given by the equation cannot possibly be accidental. But *is the relation in these and in the other cases as accurate as the excellent experimental data will permit?* Only by such an agreement could the theory be finally established. To answer this question we must examine the manner and extent to which errors in the observations will affect the constant.

A cursory examination of the equation $\frac{L - E_1}{\sqrt[3]{d} - \sqrt[3]{D}} = \text{constant}$ would make it appear that as the critical temperature is approached and *d* approaches D in value, the diminishing difference of their respective cube roots would enormously increase the proportional errors of the observations. This is, however, not the case. Substituting for L its value from equation 4 and for E_1 its value from equation 1, we have,

$$[11] \qquad \frac{0.0_431833\,(V - v)\left(\frac{\delta P}{\delta T}\,T - P\right)}{\sqrt[3]{d} - \sqrt[3]{D}} = \text{constant.}$$

Next putting $d = 1/v$ and $D = 1/V$, and simplifying, we get,

$$[12] \quad 0.0_431833\,(Vv^{1/3} + V^{2/3}v^{2/3} + V^{1/3}v)\left(\frac{\delta P}{\delta T}\,T - P\right) = \text{con.}$$

On inspection of the factor, $Vv^{1/3} + V^{2/3}v^{2/3} + V^{1/3}v$, we see:

1. That errors of observation occurring in the *density of the liquid* have at low temperatures little effect on the constant, but as the critical temperature is approached and v approaches V in value, a percentage error in the density of the liquid will cause about ⅔ of the same percentage error in the constant.

2. That errors of observation occurring in the *density of the vapor* cause at low temperatures about the same percentage errors in the constant, but as V approaches v the percentage error caused in the constant is decreased to about ⅔ of the error of the observation.

To determine the error caused by an error in the vapor pressure, we transform equation 12 into the form

$$[13] \qquad \frac{\delta P}{\delta T}\,T - P = \frac{\text{Constant}}{0.0_431833\,(Vv^{1/3} + V^{2/3}v^{2/3} + V^{1/3}v)}.$$

The right-hand side of the equation is very small at low temperatures, but increases with rise of temperature until as the critical temperature is approached the function of the volumes approaches $3V^{4/3}$.

The relative magnitude of the terms on the left-hand side of the equation must be considered. Taking water at 0° C as typical of a low vapor pressure (that it is typical will be seen if other substances are examined), we have $\frac{\delta P}{\delta T} = 0.329$, $T = 273$, $P = 4.600$, $V = 211131$, $v = 1$, and the equation takes the form $0.329 \times 273 - 4.600 = \frac{\text{Constant}}{0.0_4 31833 \times 213737}$. Since $0.329 \times 273 = 89.80$, the influence upon the constant of an error in the vapor pressure is relatively very small. T may be assumed correct, and the determining error therefore rests with the $\frac{\delta P}{\delta T}$. It is exceedingly important to note that while an error of 0.01 millimeter in the vapor pressure is an error of only *two-tenths of one per cent.* in that observation, yet if the same error exists in the $\frac{\delta P}{\delta T}$ the error so caused in the constant is *three per cent.*

For high vapor pressure considering water at 270° C (also a typical case) we have $\frac{\delta P}{\delta T} = 614$, $T = 543$, $P = 40570$ (from Biot's formula as given by Regnault), and the equation takes the form $614 \times 543 - 40570 =$ etc. And since $614 \times 573 = 351800$, it again appears that an error in the pressure produces only a very greatly diminished proportional error in the constant. It is again important to note that while an error of 20 millimetres in the pressure means an error of only *0.05 of one per cent.* in that measurement, yet this error occurring in the $\frac{\delta P}{\delta T}$ would produce an error of *more than three per cent* in that constant.

The function $\frac{\delta P}{\delta T}$ was obtained from Biot's formula (see equation 5). Biot's formula has stood the most severe tests, and I do not believe the accuracy of that formula *per se* can now be questioned.[1] But it is a purely empirical formula *fitted* to the observations. It represents a curve and primarily is but a more refined method of drawing a curve through the observations. For all points along the line of this curve one is guided by the observations on *either* side until the ends of the curve are approached. But as the ends of the curve are approached one has to be guided more and more by the trend of the curve already established. That is, along interior portions of the curve individual errors in the measurement of the pressure are smoothed out and Biot's formula is far more accurate than the individual measurements, but at the ends of the curve this smoothing is necessarily far more imperfect and Biot's formula cannot give greatly more accurate results than the individual observations. (The fact that the constants for the formula are mathematically calculated makes this observation of course none the less true.)

Individual observations of vapor pressure could not be used to obtain a correct idea of the $\frac{\delta P}{\delta T}$ *because an error in these observations is multiplied proportionately anywhere from ten to seventy times in the* $\frac{\delta P}{\delta T}$. The method adopted will keep this enormous multiplication of error from being greatly apparent, except as either end of the Biot formula curve is approached. But throughout the entire range of the observations it is doubtless this multiplication of error in the $\frac{\delta P}{\delta T}$ that is most often responsible for the variation in the constant.

Many illustrations taken directly from the measurements enforcing the above remarks might be given, but attention will only be called to the case of water. Ramsay and

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[1] **See Ramsay and Young. Phil. Trans. 1887A, p. 83.**

Young's observations of the vapor pressure of water are in beautiful accord (0° to 230° C) with the Regnault-Biot formula, whose results they quote. But when this formula is forced past the temperature (230° C) for which it was calculated, an error in the trend $\frac{\delta P}{\delta T}$ of the curve is at once apparent.[1] This error could neither have been suspected nor provided for, had either set of observations below 230° C been used to calculate the formula.

In this connection Prof. Young calls my attention to Broch's calculations of the vapor pressure of water, 0° to 100° C. Broch used the formula,

$$P = A\,10^{\frac{bt + ct^2 + dt^3 + et^4 + ft^5}{1 + at}},$$

and made exceedingly careful and laborious calculations. But unfortunately in obtaining his constants he used Regnault's data from —32° to 100° and the vapor pressures at the lower temperatures were for the most part those of ice, not water. Hence, remarks Prof. Young: "It is interesting to notice that below 0° his calculated pressures are with trifling exceptions, higher than the vapor pressures of *ice* observed by Regnault—a striking proof, if such were needed, that the vapor pressures of water are really higher than those of ice at the same temperatures. Moreover, Broch makes the vapor pressure of water at 0° = 4.569, whereas the mean of Regnault's actual observations, 12 in number, is 4.608." Again at 100° C, Prof. Young points out that the trend of Broch's curve is certainly wrong, and in proof of this he sends, and kindly permits me to publish, the following calculations upon the vapor pressure of water, made some years ago but never published.

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[1] See Phil. Trans. 1892A, p. 112.

Vapor Pressures of Water

Temperatures	From Regnault's curve	From Broch's formula	Δ
100°	760.00	760.00	0.00
120	1489.0	1544.7	55.7
150	3572.0	4244.3	672.3
200	11660.0	31861.0	20201.0

Corrected for latitude, etc. and normal degrees C.

200°	11660.0	31839.0	20179.0

Preliminary constants before employment of method of least squares

200°	11660.0	40547.0	28887.0

It surely cannot be necessary to give further illustrations of the fact that the trend of no empirical curve can be trustworthy near its end point.

In conclusion therefore:—

3. Errors of observation occurring in the vapor pressure will exert *per se* little effect upon the constant of formula 2.

4. Errors in the vapor pressure may cause greatly multiplied error in the constant by affecting Biot's formula used for the calculation of the $\frac{\delta P}{\delta T}$. This source of error will be greatly more apparent at the end points for which the Biot formula was calculated.

THE EVIDENCE FOR THE THEORY.

The measurements considered in calculating the constants, of which Table 1 gives a summary, include thirty-one substances, and cover a range of 290° in temperature. The foregoing discussion has shown that errors of observation may often be multiplied and are always compounded in their effect upon this constant. To cover this range of temperature, the number of substances, and the variously compounded errors of observation in vapor pressure, vapor density, and density of the liquid, errors which may be multiplied in the calculation, it has seemed to me reasonable to pass without discussion all variations in the constant less than two per cent. from the mean values chosen and given at the top of each column. An agreement within two per cent. of this mean value we therefore consider satisfactory. All values not showing this agreement are in black faced type.

Excepting values within ten degrees of the critical temperature the eleven substances, ethyl, oxide, di-isopropyl, isopentane, normal pentane, normal hexane, normal heptane, normal octane, benzene, hexamethylene, fluo-benzene, and carbon tetrachloride, show out of *two hundred and seventeen* observations only *two* that are not within two per cent. of the mean value adopted for that particular substance. The two exceptions are normal octane at 0° C and ethyl oxide at 180° C, and both of these divergences, as well as those occurring within ten degrees of the critical temperature, are, as shown below, easily explained.

In six of the eleven substances above mentioned, the observations allowed the tests of the formula to be carried to within one degree of the critical temperature, and in the case of normal pentane to within 0.05 of that point, yet in no case is the divergence greater than ten per cent. from the mean value adopted for that substance. Nearing the critical temperature an inspection will show that an error in the vapor pressure will be multiplied proportionately some seventy times in the constant if the error likewise affects the $\frac{\delta P}{\delta T}$ and, as already explained (p. 93), at the end points of the Biot formula curve these errors do affect, to a considerable degree, the $\frac{\delta P}{\delta T}$.

The same explanation will hold for normal octane at 0° C.

For ether at 180° C reference to the original data shows that the Biot formula adopted differs from the observations sufficiently to account for the divergence, and it is but proper here to add that Prof. Young writes: "Above 180° the substance (ether) was heated with methyl salicylate which was not quite satisfactory. In later work quinoline was used."

I think it may be safely said that every error occurring in these eleven substances could be entirely eliminated by changes in Biot's formula, in no case affecting any vapor pressure so much as five-tenths of one per cent., and I therefore emphasize the fact that *the only divergences from the theory shown by these eleven substances are not errors of observation, primarily, but of calculation.*

It may be well to mention that of the 217 observations for these eleven substances, 152 are within 1 per cent. of the average value, and the 63 that are within 2 per cent. of that value group themselves more largely at those points where errors of calculation and observation would be the greatest.

These eleven substances. therefore, from 0° C to their critical temperature, show, it seems to the author, as perfect accord with the theory as the method and observations will permit.

Of the other substances, the following observations are not within two per cent. of the mean values given.

Di-isobutyl, 120° to 190° C, inclusive, shows a divergence amounting at the greatest to five per cent. from the mean value. This may be caused by an error in the vapor density, because PΔV does not show a maximum value at 2000 mms pressure, and the same value at 5000 to 6000 mms as at 500 to 600 mms, as is the case with similar substances.

Prof. Young has very kindly examined for me his original notes and calculations upon di-isobutyl. The measurements and calculations were abundantly checked, and there would seem to be no chance for unusually large errors. He suggests that if a lower mean value were adopted the errors would be shifted toward the end points of the curve.

The author would here remark that a theory by Crompton to which attention will be called in a following paper, seems to bear out this suggestion, but also points more strongly to the fact that di-isobutyl does not give the results that similar substances would lead one to expect.

Chlor-benzene, 240° to 270° inclusive, may easily be due to the wrong trend $\frac{\delta P}{\delta T}$ of the Biot formula at this, its end point.

Brom-benzene at 30° C. The error here is due to the Biot formula, as shown by the fact that at 100° C the constant, from a theoretically calculated density is correct.

At 160° and 170° C the error may be due to the measurement of the vapor density. Prof. Young writes: "The observed volumes of saturated vapor are generally much less accurate at low temperatures than at high, because by the method employed, a given error in reading would have much greater influence at the lower temperature." Also regarding brom-benzene Prof. Young says: "After heating in ordinary daylight at 180°, 190°, 200°, 'brom-benzene slightly acted on by mercury, small quantity of solid being formed, chiefly in form of minute needle-shaped crystals.' In a second series the brom-benzene was 'carefully shielded from the light, no crystals formed.' The volumes were read in the first series only—the quantity of liquid in the second being small—and the results do not seem to me so satisfactory as with the other substances examined."

Iodo-benzene at 190° to 210° C, inclusive, may be due to measurement of vapor density. Dr. Young writes: "In the case of iodo-benzene similar crystals (to those with brom-benzene) were found, although the substance was shielded from daylight. All readings had to be taken by gas light and are therefore less accurate than usual."

The tendency towards continually increasing values of the constant with rise in temperature in the case of chlor-benzene, brom-benzene and iodo-bezene, may easily be without significance, for in the first mentioned the tendency is not marked, and in the last two the final values are not far from the probable true values as shown by the results at 30° and 100° C. On the other hand, they may indicate progressive changes commencing within the molecule, and the remarks of Dr. Young above given are significant.

Stannic chloride may be said to be in agreement with the theory from 0° C to 170° C, but the values from 100° to 280° continually decrease, and there is little doubt that the cause of the variation is operative from the first. I would call attention to the high specific heat per atom that we find in stannic chloride and the conclusion based on grounds having nothing to do with the present theory, drawn therefrom by the author,[1] viz: "A high specific heat per atom indicates that the potential energy of the atoms is being rapidly increased and that the molecule is approaching the point of dissociation."

Prof. Young writes: "Stannic chloride spoils the surface of mercury even at low temperatures and special methods had to be used throughout. The accuracy is certainly not so great as with most of the other substances, but this will not, I think, explain the regular fall in the value of the constant."

Water shows divergence 0° to 30° C and at 270° C. Both may be explained by the multiplication of error through the $\frac{\delta P}{\delta T}$ at the end points of the Biot formula curve. Ramsay and Young's observations of the vapor pressures at 230° to 270° are in themselves rather conclusive evidence that the trouble at 270° C rests with the Regnault-Biot formula.[2]

See also remarks on page 94. The measurements of Grif-

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[1] Jour. Elisha Mitchell Scientific Soc. Vol. 18.

[2] See Phil. Trans. 1892A, p. 112.

fiths would indicate that the divergence at the lower temperatures is but partly due to the vapor pressure used.

The divergence in ethyl alcohol at 0° C is probably due to its being the end point of Biot formula used.

Methyl alcohol, 210° to 238.5° C, ethyl alcohol, 190° to 242.5° C, and propyl alcohol, 120° to 260°, evidently should be grouped together. They are associated substances, as was water, and the theory was not expected to hold for associated substances, because the molecules may not be evenly distributed, the molecules are of different kinds, and the number of molecules changes with changing temperature. The fact that the theory does hold, to a very considerable degree, for these substances also, is significant, and points strongly to the conclusion that the cause of the molecular association in these substances must be the attraction which we are discussing and not some other attraction such as we might denote by the term chemical affinity. And the fact that these associated substances do not agree even more closely with the theory may be entirely due to the supposition embraced by the formula that the molecules are uniformly distributed throughout the space occupied by them—a supposition probadly untrue for associated snbstances.

Bearing in mind the comments above, we conclude that the divergences shown by di-isobutyl, chlor-benzene, brom-benzene, iodo-benzene, and water, all occur at such points and are of such magnitude (none greater than 5.4 per cent.) that they may easily be due to errors of observation, or the multiplication of such errors by the calculations. Stannic chloride fails to agree with the theory. Water, methyl, ethyl, and propyl alcohols and acetic acid are associated substances to which the theory is not applicable *a priori*, and yet these substances, acetic acid excepted, appear within limits to agree with the theory.

In conclusion, to prevent further misapprehension, I would notice a review by Mr. G. N. Lewis[1] of the former paper on

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[1] Jour. Am, Chem. Soc. 3, 107 (1903).

this subject. This paper presents additional evidence in favor of the theory, and it is the intention of the author to extend the work to the ten esters for which measurements have been made by Prof. Young. The "other assumptions of doubtful validity" upon which the present theory is based, referred to in that review, were mentioned in the original paper as they are in this (here they are numbered, however, so that he who runs may read), without attempt at proof. True equations are seldom deduced from wrong assumptions, and if we can establish the truth of the equation the assumptions will probably be admitted by those who now doubt their truth. All of the assumptions made, except possibly the law of attraction assumed, are, we are inclined to believe, regarded favorably by scientists on other grounds. Concerning the statement made in that review that "the author does not point out the simple relations between the densities of vapor and liquid, and the difference in their specific heats, which would be the direct consequence of his equations," we would say that we are of course aware that the equations that we have deduced can be combined with certain other thermodynamical, empirical and rational equations, so as to produce certain relations. (See for instance, equation 13 of this paper, which equation is similar to the relation, $p = bt - a$, of Professors Ramsay and Young.) The theory itself here given is capable of further direct and very promising application. The author hopes shortly to complete and publish a paper calling attention to some of these extensions of the theory.

For the measurements used we are indebted almost entirely to the labors of Profs. Ramsay and Young, and Prof. Young. After months of laborious acquaintance with these measurements we cannot conclude this paper without giving expression to the sincere admiration excited by the accuracy and completeness of the data they have furnished. And we would express a thanks, heartfelt, and echoed doubtless by hundreds of workers elsewhere, for their labors.

We wish further to express our thanks to Prof. Young for some unpublished details of the measurements and for comment upon the work, and we have taken the liberty of making in this paper some extracts from his letters.

SUMMARY.

1. The equation, $\frac{L - E_1}{\sqrt[3]{d} - \sqrt[3]{D}} = constant$ was deduced for the purpose of testing the assumption that the attraction between the molecules of any particular substance obeyed the law of gravitation, i. e., varied directly as the product of the masses, inversely as the square of their distance apart, and does not vary with the temperature.

2. Twenty-one substances were examined. Of these, eleven: ethyl oxide, di-isopropyl, isopentane, normal pentane, normal hexane, normal heptane, normal octane, benzene, hexamethylene, fluo-benzene, and carbon tetrachloride were, from 0° C to their critical temperature, making allowance for errors of observation and the multiplication of such errors in the calculation, in reasonably perfect agreement with the deduced equation. The divergences in di-isobutyl, chlor-benzene, brom-benzene, iodo-benzene, and water, all occur at such points and are of such magnitude that they may easily be due to the errors of observation (or the multiplication of such errors in the calculation). Stannic chloride failed to agree with the equation.

3. To the associated substances water, methyl, ethyl, and propyl alcohols, and acetic acid, the equation was not supposed applicable; but within wide limits the agreement of these substances, acetic acid excepted, is such as to suggest the conclusion that the molecular association with which we are there dealing is caused by the molecular attraction whose law we are considering.

TABLE 1.

Temperature.	Ethyl oxide	Di-iso-propyl	Di-iso-butyl	Iso-pentane	Normal pentane	Normal hexane	Normal heptane	Normal octane	Benzene	Hexa-methylene
Mean value	104.4	98.0	88.7	105.4	109.0	101.7	98.4	92.85	109.5	103.6
0°	106.5	97.8	89.1	107.2	111.1	103.6	99.6	**97.5**	109.3	102.6
10	105.6	--------	--------	104.8	--------	--------	--------	--------	--------	--------
20	104.4	--------	--------	104.5	--------	--------	--------	--------	--------	--------
30	103.9	--------	--------	104.1	107.6	--------	--------	--------	--------	--------
40	103.5	--------	--------	104.3	108.5	--------	--------	--------	--------	--------
50	103.4	98.6	--------	104.5	109.3	--------	--------	--------	--------	--------
60	103 4	98.7	--------	104.7	109.5	102.4	--------	--------	--------	--------
70	103.5	99.0	--------	104.6	109.6	102.7	100.3	--------	--------	--------
80	103.5	98.4	--------	105.2	109.7	103.0	99.4	--------	107.8	--------
90	103.9	98.2	90.4	105.5	109.9	103.0	99.1	--------	107.8	105.6
100	103.5	97.8	88.7	105.8	109.9	103.3	99.0	--------	108.1	104.8
110	104.7	97.4	87.0	106.0	110.4	103.7	98.9	--------	108.3	104.1
120	104.8	97.6	**85.8**	106.3	111.1	103.6	98.3	91.2	108.6	103.3
130	104.9	97.7	**85.0**	106.5	111.0	103.5	97.8	91.4	108.8	102.5
140	105.5	97.7	**84.9**	106.7	110.5	103.2	97.5	91.8	109.1	102.1
150	105.3	99.7	**84.6**	106.9	110.5	103.1	97.2	92.1	109.4	102.2
160	104.4	97.7	**85.1**	106.7	110.3	102.5	97.5	92.8	109.5	102.7
170	103.0	97.7	**85.7**	105.5	110.3	102.4	97.7	92.8	109.8	103.1
180	**101.0**	98.0	**86.2**	103.4	109.3	102.6	98.5	92.9	110.0	103.4
190	106.3	98.1	**86.8**	187.4° **96.6**	**106.3**	102.8	98.9	93.1	110.4	102.9
200	193° **114.5**	98.1	87.0	--------	197.15° **98.8**	102.7	99.2	93.3	110.5	103.1
210	--------	97.3	87.3	--------	--------	102.1	99.7	93.9	110.5	103.5
220	--------	**94.8**	87.9	--------	--------	101.1	99.7	93.6	110.7	104.2
230	--------	225° **92.0**	88.6	--------	--------	**98.0**	99.8	93.9	111.1	104.6
240	--------	--------	89.0	--------	--------	234° **94.2**	99.8	93.7	110.6	104.6
250	--------	--------	89.5	--------	--------	--------	99.3	94.2	110.3	104.9
260	--------	--------	89.4	--------	--------	--------	96.6	94.6	110.0	104.7
270	--------	--------	87.6	--------	--------	--------	266.5° **90.8**	94.3	110.0	103.4
280	--------	--------	274° **86.4**	--------	--------	--------	--------	93.4	107.8	279° **98.1**
290	--------	--------	--------	--------	--------	--------	--------	91.0	--------	--------
Critic'l temp.	194°	227.35°	276.8°	187.8°	197.2°	234.8°	266.9°	296.2°	288.5°	279.95°

TABLE 1.—*Continued.*

Temperature	Fluobenzene	Chlorbenzene	Brombenzene	Iodobenzene	Carbon tetrachloride	Stannic chloride	Water	Methyl alcohol	Ethyl alcohol	Propyl alcohol	Acetic acid
Mean value	85.7	81.0	56.1	44.2	44.3	26.0	556.0	302.3	240.1	199.2	------
0	84.6	81.6	------	------	43.53	26.20	**585.7**	304.7	**232.8**	203.1	------
10	------	------	------	------	------	------	**580.1**	306.0	235.4	------	------
20	------	------	------	------	------	------	**575.2**	306.6	237.4	------	**81.3**
30	------	------	**58.74**	44.99	------	------	**570.7**	307.9	239.9	------	**83.8**
40	------	------	------	------	------	------	566.6	307.4	241.7	------	**86.1**
50	------	------	------	------	------	------	563.0	308.3	242.4	------	**87.8**
60	------	------	------	------	------	------	559.9	308.0	243.6	------	**90.4**
70	------	------	------	------	------	------	556.9	308.1	244.1	----	**92.2**
80	86.8	------	------	------	------	------	554.5	307.8	244.9	199.9	**94.7**
90	87.2	------	------	------	43.52	------	552.4	307.1	244.6	199.2	**96.4**
100	86.9	------	56.93	44.65	43 58	26.45	550.6	306.3	244.8	197.6	**98.5**
110	86.7	------	------	------	43.58	26.34	549.5	306.0	242.7	196.2	**100.7**
120	86.3	------	------	------	43.64	26.24	548.6	305.4	242.1	**193.6**	**104.3**
130	85.7	79.5	------	------	43.67	26.16	547.8	304.5	241.0	**191.3**	**104.9**
140	85.0	80.3	------	------	43.79	26.00	547.6	304.1	241.0	**191.1**	**105.5**
150	84.6	81.1	------	------	43.79	25.82	547 3	301.3	241.1	**187.8**	**106.6**
160	84.7	80.8	**54.09**	------	43.83	25.68	547 8	303.1	239.8	**185.6**	**107.9**
170	84.7	81.3	**54.48**	------	43.86	25.46	548.7	302.3	238.2	**184.1**	111.7
180	84.7	81.2	54.98	------	43.92	**25.13**	550.4	300.9	236.5	**182.7**	111.3
190	84.8	81.3	55.21	**41.87**	44.00	**24.84**	551.8	300.8	**233.3**	**180.4**	113.3
200	84.7	81.3	55.45	**42.66**	44.16	**24.68**	553.9	299.3	**230.0**	**178.6**	115.4
210	85.1	81.6	55.91	**43.06**	44.34	**24.45**	556.4	**295.4**	**226.3**	**176.6**	117.5
220	85.5	81.8	55.87	43.64	44.55	**24.20**	559.1	**287.6**	**223.0**	**173.2**	119.1
230	85.8	82.3	56.25	43.73	44.76	**23.96**	563.0	**276.5**	**219.7**	**168.8**	121.5
240	86.2	**83.1**	56.19	44.03	44.94	**23.63**	553.6	{238 5° {**259.4**	**209.2**	**164.1**	124.1
250	86.6	**83.6**	56.44	44.38	45.16	**23.35**	551.0	------	{242.5° {**197.2**	**160 2**	126.4
260	86.8	**84.3**	56 92	44.68	44.99	**22.96**	544.9	------	------	**157.0**	128.4
270	86.3	**84.9**	57.15	45.10	44.47	**22.47**	**535 5**	------	------	------	130.0
280	84.7	------	------	------	43.90	**22.15**	------	------	------	------	131.5
290	------	------	------	------	------	------	------	------	------	------	131.2
Crit'l temp	286.55°	360.7°	397°	448°	283.15°	318.7°	365°	240°	243.6°	263.7°	321.65°

TABLE 2

Ethyl Oxide.

Temperature	Pressure.	Density of liquid	Density of vapor	Latent heat	E_1	$L - E_1$	$d^{1/3} - D^{1/3}$	$\frac{L - E_1}{d^{1/3} - D^{1/3}}$
0°	184.90	0.7362	0.0008270	93.27	7.11	86.16	0.8091	106.5
10	291.78	0.7248	0.001264	90.77	7.33	83.44	0.7901	105.6
20	442.36	0.7135	0.001870	87.90	7.50	80.40	0.7704	104.4
30	647.93	0.7019	0.002677	85.60	7.68	77.92	0.7499	103.9
40	921.18	0.6894	0.003731	83.18	7.82	75.36	0.7283	103.5
50	1276.11	0.6764	0.005079	80.95	7.94	73.01	0.7059	103.4
60	1728.13	0.6658	0.006771	78.84	8.05	70.79	0.6840	103.4
70	2293.91	0.6532	0.008920	76.42	8.07	68.35	0.6603	103.5
80	2991.40	0.6402	0.01155	73.95	8.10	65.85	0.6359	103.5
90	3839.71	0.6250	0.01477	71.39	8.08	63.31	0.6096	103.9
100	4859.01	0.6105	0.01867	68 35	8.02	60.33	0 5830	103.5
110	6070.38	0.5942	0.02349	65.98	7.91	58.07	0.5543	104.7
120	7495.73	0.5764	0.02934	62.63	7.72	54.91	0.5238	104.8
130	9157.42	0.5580	0.03638	59.11	7.49	51.62	0.4919	104.9
140	11078.2	0.5385	0.04488	55.52	7.21	48.31	0.4582	105.5
150	13281.0	0.5179	0.05551	51.18	6.80	44 38	0.4216	105.3
160	15788.1	0.4947	0.06911	45.99	6.25	39.74	0.3805	104.4
170	18622.2	0.4658	0.08731	39.69	5.51	34.18	0.3315	103.0
180	21804.3	0.4268	0.1135	31.58	4.49	27.09	0.2687	101.0)
185	23532.4	0.4018	0.1320	26.78	3.82	22.96	0.2287	100.4)
190	25355.1	0.3663	0.1620	20.90	2.79	18.11	0.1704	106.3
182	26111.2	0.3448	0.1826	17.10	2.14	14.96	0.1339	111.6)
193	26495.0	0.3300	0.2012	13.67	1.67	12.03	0.1051	114.5)

TABLE 3

Di-isopropyl

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p.\Delta v.\ T}{10^6}$	A	Latent heat	E_1	$L - E_1$	$d^{1/3}-D^{1/3}$	$\frac{L-E_1}{d^{1/3}-D^{1/3}}$
0°	76.05	0.6795	0.0003840	54.05	1.57468	85.11	6.30	78.81	0.8065	97.81
50	584.1	0.6338	0.002551	73.64	1.06573	78.47	7.26	71.21	0.7224	98.57
60	806.8	0.6243	0.003448	77.49	0.99238	76.90	7.41	69.49	0.7036	98.75
70	1090.3	0.6144	0.004566	81.29	0.92634	75.30	7.54	67.76	0.6842	99.03
80	1444.8	0.6039	0.006006	84.05	0.86685	72.86	7.58	65.28	0.6635	98.39
90	1880.9	0.5931	0.007752	86.90	0.81327	70.67	7.62	63.05	0.6423	98.16
100	2409.7	0.5821	0.009901	89.26	0.76498	68.28	7.61	60.67	0.6203	97.81
110	3043.0	0.5708	0.01250	91.15	0.72144	65.76	7.58	58.18	0.5974	97.38
120	3793.2	0.5589	0.01555	93.18	0.68219	63.57	7.54	56.03	0.5741	97.60
130	4673.0	0.5464	0.01923	94.54	0.64677	61.15	7.47	53.68	0.5496	97.69
140	5697.0	0.5334	0.02358	95.28	0.61479	58.58	7.34	51.24	0,5242	97.75
150	6879.0	0.5197	0.02825	97.46	0.58592	57.10	7.33	49.77	0.4994	99.67
160	8234.0	0 5049	0.03521	94.13	0.55982	52.70	6.92	45.78	0.4685	97.72
170	9781.0	0.4885	0.04292	92.05	0.53623	49.36	6.61	42.75	0.4375	97.71
180	11536.0	0.4705	0.05216	89.06	0.51488	45.86	6.26	39.60	0.4042	97.98
190	13519.0	0.4508	0.06361	84.50	0 49555	41.87	5.81	36.06	0.3676	98.09
200	15752.0	0.4274	0.07831	77.71	0.47803	37.15	5.23	31.92	0.3255	98.07
210	18258.0	0.3988	0.09862	67.28	0.46213	31.09	4.43	26.66	0.2741	97.27
216	19905.0	0.3758	0.1163	57.80	0.45331	26.20	3.76	22.44	0.2335	96.10
220	21062.0	0.3565	0.1321	49.45	0.44770	22.14	3.19	18,95	0.1998	94.84)
225	22585.0	0.3198	0.1649	33.04	0.44099	14.57	2.11	12.46	0.1355	91.96)

TABLE 4

Di-isobutyl

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p.\Delta v.\ T}{10^6}$	A	Latent heat	E_1	$L - E_1$	$d^{1/3}-D^{1/3}$	$\frac{L-E_1}{d^{1/3}-D^{1/3}}$
0°	7.11	0 7102	0.00004762	40.76	1.98712	80.99	4.75	76.24	0.8560	89.06
90	425.6	0.6328	0.002174	70.82	1.01836	72.12	6.21	65.91	0.7290	90.41
100	581.1	0.6236	0.002967	72.70	0.95256	69.25	6.20	63.05	0.7106	88.73
110	777.9	0.6143	0.003984	74.30	0.89276	66.33	6.17	60.16	0.6916	86.98
120	1022.6	0.6046	0.005236	76.08	0.83846	63.79	6.16	57.63	0.6720	85.76)
130	1322.5	0.5945	0.006757	77.98	0.78921	61.54	6.16	55.38	0.6517	84.97)
140	1684.9	0.5841	0.008532	80.37	0.74460	59.84	6.19	53.65	0.6316	84.94)
150	2118.2	0.5732	0.01072	82.06	0.70425	57.79	6.17	51.62	0.6102	84.59)
160	2630.6	0.5620	0.01319	84.30	0.66783	56.30	6.19	50.11	0.5889	85.09)
170	3231.3	0.5503	0.01610	86.30	0.63500	54.80	6.20	48.60	0.5670	85 71)
180	3930.2	0.5383	0.01957	87.61	0.60549	53.05	6.15	46.90	0.5440	86.21)
190	4738.0	0.5255	0.02370	88.39	0.57903	51.18	6.08	45.10	0.5197	86.78)
200	5666.5	0.5117	0.02874	87.93	0.55539	48.83	5.92	42.91	0.4935	86.96
210	6729.5	0.4970	0.03484	86.80	0.53433	46.38	5.72	40.66	0.4655	87.34
220	7941.0	0.4810	0.04202	84.94	0.51566	43.80	5.48	38.32	0.4358	87.93
230	9319.0	0.4633	0.05094	81.89	0.49918	40.88	5.18	35.70	0.4031	88.56
240	10883.0	0.4434	0.06223	77.10	0.48474	37.37	4.78	32.59	0.3663	88.97
250	12654.0	0.4199	0.07680	70.40	0.47218	33.24	4.28	28.96	0.3237	89.47
260	14660.0	0.3912	0.09699	60.55	0.46135	27.93	3.62	24.31	0.2719	89.41
270	16929.0	0.3482	0.1321	43.21	0.45213	19.54	2.53	17.01	0.1942	87.58
274	18006,0	0.3187	0.1572	31.72	0.44887	14.24	1.85	12.39	0.1434	86.40)

TABLE 5

Isopentane

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p.\Delta v.T}{10^6}$	A	Latent heat	E_1	$L-E_1$	$d^{1/3}-D^{1/3}$	$\frac{L-E_1}{d^{1/3}-D^{1/3}}$
0°	257.74	0.6392	0.001090	64.43	1.37910	88.86	7.51	81,35	0.7585	107.2
10	390.52	0.6295	0.001646	66.96	1.26846	84.93	7.53	77.40	0.7389	104.8
20	572.59	0.6196	0.002358	70.88	1.16990	82.91	7.70	75.21	0.7194	104.5
30	815.34	0.6092	0.003300	74.45	1.08206	80.55	7.82	72.73	0.6988	104.1
40	1131.1	0.5988	0.004480	78.41	1.00375	78.69	7.97	70.72	0.6781	104.3
50	1533.2	0 5881	0.005967	82.14	0.93390	76.71	8.09	68.62	0.6564	104.5
60	2035.6	0.5769	0.007819	85.55	0.87157	74.56	8.18	66.38	0.6340	104.7
70	2653.0	0.5656	0.01011	88.36	0.81591	72.09	8.20	63.89	0.6107	104.6
80	3400.8	0.5540	0.01284	91.36	0.76618	70.00	8.24	61.76	0.5871	105.2
90	4295.6	0.5413	0.01617	93.54	0.72171	67.51	8.20	59.31	0.5621	105.5
100	5354.5	0.5278	0.02022	95.00	0.68194	64.78	8.11	56.67	0.5357	105.8
110	6596.1	0.5140	0.02513	95.64	0.64631	61.81	7.95	53.86	0.5081	106.0
120	8039.9	0.4991	0.03106	95.42	0.61439	58.62	7.73	50.89	0.4788	106.3
130	9706.7	0.4826	0.03831	94.02	0.58574	55.07	7.43	47.64	0.4473	106.5
140	11620.0	0.4642	0.04728	91.19	0.56002	51.07	7.03	44.04	0.4127	106.7
150	13804.0	0.4445	0.05834	86.92	0.53689	46.67	6.54	40.13	0.3754	106.9
160	16285.0	0.4206	0.07289	79.98	0.51605	41.27	5.88	35.39	0.3316	106.7
170	19094.0	0.3914	0.09337	68.93	0.49728	34.28	4.95	29.33	0.2778	105.5
176	20950.0	0.3694	0.1101	59.90	0.48690	29.17	4.25	24.92	0,2382	104.6
180	22262.0	0.3498	0.1258	51.33	0.48031	24.65	3.61	21.04	0.2035	103.4
183	23288.0	0.3311	0.1418	42.80	0.47555	20.35	2.99	17.36	0.1703	101.9)
185	23992.0	0.3142	0.1574	34.86	0.47245	16.47	2.42	14.05	0.1399	100.4)
186	24350.0	0.3028	0.1676	29.76	0.47093	14.01	2.06	11.95	0.1201	99.5)
187	24713.0	0.2857	0.1833	22.22	0.46942	10.43	1.54	8.89	0.0905	98.2)
187.4	24880.0	0.2761	0.1951	17.21	0.46882	8.07	1.19	6.88	0.0712	96.6)

TABLE 6

Normal Pentane

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p.\Delta v.T}{10^6}$	A	Latent heat	E_1	$L-E_1$	$d^{1/3}-D^{1/3}$	$\frac{L-E_1}{d^{1/3}-D^{1/3}}$
0°	183.40	0.6454	0.0007756	64.48	1.44799	93.36	7.51	85.85	0.7723	111.1
30	613.9	0.6165	0.002475	74.84	1.13456	84.91	7 86	77,05	0.7158	107.6
40	865.3	0.6062	0.003390	79.47	1.05221	83.63	8.08	75.55	0.6961	108.5
50	1190.2	0.5957	0.004545	83.91	0.97878	82.13	8.27	73.86	0.6758	109.3
60	1601.8	0.5850	0.006024	87.65	0.91324	80.04	8.38	71.66	0.6544	109.5
70	2114.0	0.5739	0.007868	90.93	0.85466	77.71	8.44	69.27	0.6321	109.6
80	2742.1	0.5624	0.01013	93.86	0.80221	75.30	8.46	66.84	0.6091	109.7
90	3501.5	0.5503	0.01289	96.30	0.75519	72.73	8.45	64.28	0.5850	109.9
100	4409.1	0.5378	0.01627	97.99	0.71297	69.87	8.36	61.51	0.5598	109.9
110	5482.5	0.5248	0.02026	99.62	0.67497	67.24	8.28	58.96	0.5340	110.4
120	6740.5	0.5107	0.02503	100.65	0.64073	64.48	8.15	56.33	0.5068	111.1
130	8203.0	0.4956	0.03106	99.78	0.60979	60.85	7.88	52.97	0.4770	111.0
140	9890.0	0.4787	0.03861	97.26	0.58177	56.58	7.50	49.08	0 4442	110.5
150	11826.0	0.4604	0.04762	94.16	0.55636	52.39	7.09	45.30	0.4097	110.5
160	14032.0	0.4394	0.05910	88.94	0.53323	47.42	6.53	40.89	0.3707	110.3
170	16535.0	0.4161	0.07347	82.13	0.51213	42.06	5.90	36.16	0.3278	110.3
180	19362.0	0.3867	0.09354	71.03	0.49284	35.01	4.99	30.02	0.2746	109.3
186	21225.0	0.3643	0.1109	61.14	0.48205	29.47	4.24	25.23	0.2337	108.0
190	22540.0	0.3445	0.1269	51.95	0.47516	24.68	3.57	21.11	0.1985	106.3)
193	23566.0	0.3253	0.1441	42.50	0.47014	19.98	2.90	17.08	0.1634	104.5)
195	24271.0	0.3065	0.1609	33.54	0.46685	15.66	2.28	13.38	0.1303	102.7)
196	24629.0	0.2915	0.1745	26.55	0.46524	12.35	1.80	10.55	0.1042	101.2)
196.5	24810.0	0.2809	0.1842	21.78	0.46443	10.12	1.48	8.64	0.0859	100.6)
197.0	24991.0	0.2640	0.2004	14.12	0.46363	6.55	0.96	5.59	0.0563	99.3)
197.1	25027.0	0.2560	0.2090	10.34	0.46347	4.79	0.70	4.09	0.0415	98.5)
197.15	25045.0	0.2472	0.2167	6.71	0.46339	3.11	0.45	2.66	0.0269	98.8)

TABLE 7

Normal Hexane

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p.\Delta v.T}{10^6}$	A	Latent heat	E_1	$L - E_1$	$d^{1/3} - D^{1/3}$	$\frac{L - E_1}{d^{1/3} - D^{1/3}}$
0°	44 92	0.6770	0.0002268	54.05	1.68307	90.98	6.30	84.68	0.8171	103.6
60	567.62	0.6221	0.00249	75.68	1.06787	80.82	7.23	73.59	0.7182	102.4
70	784.80	0.6122	0.00337	79.51	0.99598	79.19	7.38	71.81	0.6992	102.7
80	1062.0	0.6022	0.00446	83,31	0.93083	77.55	7.51	70.04	0.6799	103.0
90	1409.0	0.5918	0.00585	86.61	0.87180	75.51	7.60	67.91	0.6594	103.0
100	1838.0	0.5814	0.00752	90.00	0.81835	73.65	7 68	65.97	0.6387	103.3
110	2358.0	0.5703	0.00952	93.18	0.76998	71.75	7.74	64.01	0.6174	103.7
120	2982.0	0.5588	0.01200	95.54	0.72623	69.38	7.74	61.64	0.5947	103.6
130	3723.0	0,5467	0.01502	97.24	0.68669	66.78	7.68	59.10	0.5710	103.5
140	4593.0	0.5343	0.01862	98.25	0.65098	63.96	7.57	56.39	0.5464	103 2
150	5606.0	0.5207	0.02299	98.64	0.61874	61.03	7.42	53.61	0.5201	103.1
160	6778.0	0.5063	0.02833	97.73	0.58968	57.63	7.18	50.45	0.4921	102.5
170	8123.0	0.4913	0.03472	96.44	0.56352	54.34	6.93	47.41	0.4629	102.4
180	9659.0	0.4751	0.04228	94.31	0.53998	50.93	6 63	44.30	0.4319	102.6
190	11407.0	0.4570	0.05155	90.89	0.51883	47.16	6.25	40.91	0.3981	102.8
200	13385.0	0.4365	0.06329	85.52	0.49986	42.75	5.75	37.00	0.3601	102.7
210	15619.0	0.4124	0.07900	77,23	0.48289	37.29	5.09	32.20	0.3152	102.1
220	18133.0	0.3809	0.1011	64.93	0.46773	30.37	4.19	26.18	0.2590	101.1
226	19788.0	0,3557	0.1203	53.97	0.45943	24.79	3.46	21.33	0.2148	99.3)
230	20957.0	0.3329	0.1404	43.43	0.45421	19.73	2.75	16.98	0 1732	98.0)
233	21870.0	0.3040	0.1658	30.32	0.45045	13.66	1.90	11.76	0.1230	95.6)
234	22181.0	0 2883	0.1807	23.24	0.44923	10.44	1.46	8.98	0.0953	94.2)

TABLE 8

Normal Heptane

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p.\Delta v.T}{10^6}$	A	Latent heat	E_1	$L - E_1$	$d^{1/3} - D^{1/3}$	$\frac{L - E_1}{d^{1/3} - D^{1/3}}$
0°	11.45	0.7005	0.00006725	46.46	1.93423	89.86	5.42	84.44	0.8474	99.6
70	302.77	0.6402	0.001435	72.17	1.13368	81.84	6.70	75.14	0.7491	100,3
80	427.10	0.6311	0.001996	75.22	1.05722	79.52	6.78	72.74	0.7319	99.4
90	588.74	0.6218	0.002703	78.66	0.98784	77.70	6.90	70.80	0.7142	99.1
100	794.93	0.6124	0.003584	82.13	0.92493	75.96	7.01	68.95	0.6962	99.0
110	1053.3	0.6027	0.004692	85.33	0.86789	74.06	7.09	66.97	0.6773	98.9
120	1372.1	0.5926	0.006068	87.95	0.81624	71.79	7.12	64.67	0.6576	98.3
130	1759.9	0.5821	0,007752	90.27	0.76948	69.46	7.13	62.33	0.6371	97.8
140	2226.1	0.5711	0.009775	92.39	0.72719	67.19	7.12	60.07	0.6159	97.5
150	2780.4	0.5598	0.01222	94.08	0.68898	64.81	7.08	57.73	0.5939	97.2
160	3433.3	0.5481	0.01508	95.87	0.65447	62.74	7.05	55.69	0.5713	97.5
170	4196.0	0.5359	0.01848	97.02	0,62337	60.48	6.97	53.51	0.5479	97.7
180	5080.9	0 5232	0.02242	98.30	0.59536	58.52	6.90	51.62	0.5238	98.5
190	6101.3	0.5096	0.02717	98.30	0.57017	56.05	6.76	49.29	0.4982	98.9
200	7271.8	0.4952	0.03304	97.14	0.54757	53.17	6.54	46.63	0.4703	99.2
210	8608.6	0.4793	0.04005	95.15	0.52730	50.17	6.27	43.90	0.4405	99.7
220	10130.0	0.4616	0.04892	91.25	0.50919	46.46	5.89	40.57	0.4071	99.7
230	11857.0	0.4414	0.06002	85.81	0.49305	42.31	5.43	36.88	0.3698	99.8
240	13811.0	0.4177	0.07446	78.24	0.47869	37.45	4.85	32.60	0.3268	99.8
250	16020.0	0.3877	0.09461	67.05	0.46598	31.25	4.08	27.17	0.2735	99.3
260	18511.0	0.3457	0.1287	48.15	0.45475	21.90	2.88	19.02	0.1969	96.6
264	19595.0	0.3166	0.1538	35.15	0.45066	15.84	2.08	13.76	0.1458	94.4)
266	20150.0	0.2907	0.1778	23.73	0.44869	10.65	1.40	9.25	0.1001	92.4)
266.5	20300.0	0.2819	0.1895	8.97	0.44821	8.50	1.12	7.38	0.0813	90.8)

TABLE 9

Normal Octane

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p.\Delta v.T}{10^6}$	A	Latent heat.	E_1	$L - E_1$	$d^{1/3}—D^{1/3}$	$\frac{L - E_1}{d^{1/3}—D^{1/3}}$
0°	2.90	0.7185	0.00001942	40.77	2.1942	89.46	4.75	84.71	0.8688	97.50)
120	649.3	0.6168	0.003300	76.91	0.91369	70.27	6.24	64.03	0.7023	91.17
130	859.4	0.6071	0.004292	80.16	0.85906	68.86	6.33	62.53	0.6842	91.39
140	1114.5	0.5973	0.005464	83.47	0.80944	67.56	6.43	61.13	0.6661	91.77
150	1426.9	0.5875	0.006897	86.50	0.76440	66.12	6.51	59.61	0.6471	92.12
160	1802.4	0.5772	0.008584	89.59	0.72354	64.82	6.58	58.24	0.6278	92.77
170	2249.0	0.5667	0.01065	91.74	0.68649	62.98	6.59	56.39	0.6075	92.82
180	2775.4	0.5556	0.01314	93.41	0.65293	60.99	6.56	54.43	0.5861	92.87
190	3390.7	0.5441	0.01608	94.82	0.62252	59.03	6.52	52.51	0.5640	93.10
200	4105.0	0.5317	0.01957	95.54	0.59501	56.87	6.43	50.44	0.5406	93.30
210	4928.9	0.5189	0.02364	96.17	0.57015	54.83	6.34	48.49	0.5166	93.86
220	5874.6	0.5053	0.02874	95.00	0.54769	52.03	6.13	45.90	0.4902	93.63
230	6955.0	0.4901	0.03484	93.41	0.52743	49.27	5.91	43.36	0.4618	93.90
240	8184.5	0.4732	0.04237	90.29	0.50918	45.97	5.60	40.37	0.4307	93.73
250	9578.8	0.4554	0.05118	86.87	0.49276	42.80	5.29	37.51	0.3981	94.22
260	11156.0	0.4364	0.06223	81.87	0.47802	39.14	4 89	34.25	0.3622	94.56
270	12937.0	0.4123	0.07716	73.96	0.46480	34.38	4.33	30.05	0.3186	94.32
280	14942.0	0.3818	0.09833	62.38	0.45298	28.26	3.59	24.67	0.2639	93.40
290	17198.0	0.3365	0.1346	43.18	0.44243	19.10	2.44	16.66	0.1831	91.00

TABLE 10

Benzene

Temperature	Pressure	Density of liquid	Density of vapor	Latent heat	E_1	$L - E_1$	$d^{1/3}—D^{1/3}$	$\frac{L—E_1}{d^{1/3}—D^{1/3}}$
0°	26.54	0.9001	0.0001215	107.05	6.95	100.10	0.9160	109.3
80	753.62	0.8145	0.002722	94.40	8.78	85.62	0.7943	107.8
90	1016.1	0.8041	0.003570	92.76	9.02	83.74	0.7771	107.8
100	1344.3	0.7927	0.004690	91.05	9.07	81.98	0.7581	108.1
110	1748.2	0.7809	0.006035	89.20	9.15	80.05	0.7388	108.3
120	2238.1	0.7692	0.007634	87.36	9.24	78.12	0.7194	108.6
130	2824.9	0.7568	0.009515	85.43	9.33	76.10	0.6994	108.8
140	3520.0	0.7440	0.01174	83.48	9.39	74.09	0.6789	109.1
150	4334.8	0.7310	0.01436	81.35	9.42	71.93	0.6577	109.4
160	5281.9	0.7185	0.01734	79.20	9.46	69.74	0.6368	109.5
170	6374.1	0.7043	0.02087	76.90	9.43	67.47	0.6144	109.8
180	7625.2	0.6906	0,02487	74.53	9.41	65.12	0.5920	110.0
190	9049.4	0.6758	0.02977	71.93	9.25	62.68	0.5676	110.4
200	10663.0	0.6605	0.03546	69.01	9.06	59.95	0.5424	110.5
210	12482.0	0.6432	0.04207	65.80	8.83	56.97	0.5154	110.5
220	14526.0	0.6255	0.05015	62.32	8.48	53.84	0.4864	110.7
230	16815.0	0.6065	0.06024	58.49	8.00	50.49	0.4545	111.1
240	19369.0	0.5851	0.07138	54.21	7.58	46.63	0.4216	110.6
250	22214.0	0.5609	0.08554	49.40	7.01	42.39	0.3841	110.3
260	25376.0	0.5328	0.1038	43.76	6.27	37.49	0.3407	110.0
270	28885.0	0.4984	0.1287	36.97	5.30	31.67	0.2880	110.0
280	32772.0	0.4514	0.1660	27.43	3.98	23.45	0.2175	107.8

TABLE 11
Hexamethylene

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p.\Delta v.T}{10^6}$	A	Latent heat	E_1	$L - E_1$	$d^{1/3}-D^{1/3}$	$\frac{L - E_1}{d^{1/3}-D^{1/3}}$
0°	27.85	0.7967	0.0001374	55.34	1.73860	96.22	6.45	89.77	0.8754	102.6
90	992.34	0.7106	0.003759	95.32	0.90396	86.17	8.36	77.81	0.7369	105.6
100	1306.8	0.7003	0.004902	98.77	0.84748	83.71	8.43	75.28	0.7181	104.8
110	1691.0	0.6898	0.006289	102.03	0.79610	81.23	8.48	72.75	0.6990	104.1
120	2155.4	0.6791	0.007968	105.01	0.74938	79.69	8.51	70.18	0.6793	103.3
130	2709.1	0.6680	0.01000	107.52	0.70695	76.01	8.49	67.52	0.6588	102.5
140	3362.0	0.6565	0.01238	110.11	0.66844	73.60	8.49	65.11	0.6378	102.1
150	4124.5	0.6448	0.01508	112.90	0.63349	71.52	8.49	63.03	0.6168	102.2
160	5007.3	0.6325	0.01818	115.78	0.60183	69.68	8.51	61.17	0.5955	102.7
170	6021.9	0.6200	0.02183	117.93	0.57314	67.59	8.47	59.12	0.5732	103.1
180	7199.9	0.6067	0.02625	119.05	0.54721	65.15	8.36	56.79	0.5494	103.4
190	8494.5	0.5926	0.03140	118.62	0.52377	62.13	8.15	53.98	0.5245	102.9
200	9980.2	0.5780	0.03738	118.11	0.50263	59.37	7.95	51.42	0.4986	103.1
210	11651.0	0.5626	0.04437	116.84	0.48358	56.50	7.70	48.80	0.4715	103.5
220	13526.0	0.5456	0.05249	114.82	0.46645	53.56	7.41	46.15	0.4427	104.2
230	15622.0	0.5271	0.06250	110.81	0.45107	49.98	7.01	42.97	0.4109	104.6
240	17961.0	0.5063	0.07496	104.65	0.43732	45.76	6.49	39.27	0.3754	104 6
250	20565.0	0.4820	0.09058	96.52	0.42504	41.02	5.87	35.15	0.3350	104.9
260	23461.0	0.4533	0.1111	84.91	0.41409	35.16	5.07	30.09	0.2874	104.7
270	26680.0	0.4125	0.1433	66.68	0.40441	26.72	3.87	22.85	0.2210	103.4
277	29140.0	0.3642	0.1855	42.31	0.39829	16.85	2.45	14.40	0.1438	100.1
279	29878.0	0.3593	0.2105	29.69	0.39664	11.78	1.71	10.07	0.1026	98.1

TABLE 12
Fluo-benzene

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p.\Delta v.T}{10^6}$	A	Latent heat	E_1	$L - E_1$	$d^{1/3}-D^{1/3}$	$\frac{L - E_1}{d^{1/3}-D^{1/3}}$
0°	20.92	1.0465	0.0001179	48.43	1.80422	87.39	5.65	81.74	0.9662	84.60
80	645.98	0.9496	0.002885	78.79	1.01612	80.06	7.10	72.96	0.8405	86.80
90	879.73	0.9366	0.003831	83.03	0.95108	78.97	7.28	71.69	0.8219	87.22
100	1174.9	0.9233	0.005040	86.46	0.89163	77.09	7.38	69.71	0.8023	86.86
110	1541.3	0.9096	0.006515	89.97	0.83731	75.33	7.48	67.85	0.7821	86.75
120	1989 2	0.8955	0.008333	92.94	0.78772	73.21	7.53	65 68	0.7611	86.29
130	2529.5	0.8811	0.01055	95.49	0.74249	70.90	7.54	63.36	0.7394	85.69
140	3173.0	0.8665	0.01321	97.67	0.70128	68.50	7.53	60.97	0.7170	85.03
150	3931.4	0.8519	0.01634	99.78	0 66379	66.26	7.51	58.75	0.6942	84.63
160	4816.7	0.8363	0.01992	102.23	0.62970	64.37	7.51	56.86	0.6711	84.73
170	5841.6	0.8203	0.02413	104.08	0.59878	62.32	7.48	54.84	0.6471	84.74
180	7018.9	0.8037	0.02911	105.28	0.57076	60.09	7.40	52.69	0.6221	84.70
190	8363.5	0.7857	0.03496	105.84	0.54542	57.83	7.28	50.55	0.5958	84.85
200	9890.5	0.7671	0.04184	105.71	0.52257	55.24	7.11	48.13	0.5683	84.66
210	11617.0	0.7480	0.04968	105.43	0.50202	52.93	6.95	45.98	0.5401	85.09
220	13561.0	0.7265	0.05907	103.97	0.48356	50.28	6.71	43.57	0.5095	85.51
230	15745.0	0.7036	0.07037	101.30	0.46708	47.32	6.41	40.91	0.4766	85.84
240	18190.0	0.6789	0.08403	97.32	0.45241	44.03	6.04	38.00	0.4409	86.19
250	20924 0	0.6504	0.1008	91.70	0.43941	40.29	5.58	34.71	0.4010	86.58
260	23977.0	0.6163	0.1226	83.50	0.42796	35.74	5.99	30.75	0.3541	86.85
270	27384.0	0.5739	0.1535	70.96	0.41796	29.66	4.16	25.50	0.2956	86.26
280	31182.0	0.5133	0.2034	51.20	0.40928	20.95	2.95	18.00	0.2126	84.69

TABLE 13

Chlor-benzene

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p.\Delta v.T}{10^6}$	A	Latent heat	E_1	$L-E_1$	$d^{1/3}-D^{1/3}$	$\frac{L-E_1}{d^{1/3}-D^{1/3}}$
0°	2.56	1.1278	0.00001689	41.36	2.12075	87.72	4.82	82.90	1.0152	81.65
130	720.03	0.9836	0.003409	84.81	0.86978	73.77	6.70	67.07	0.8440	79.46
140	938.84	0.9723	0.004316	89.45	0 82021	73.37	6.89	66.48	0.8279	80.30
150	1206.0	0.9599	0.005394	94.06	0.77491	72.89	7.08	65.81	0.8111	81.13
160	1528.3	0.9480	0.006761	97.14	0.73356	71.26	7.14	64.12	0.7933	80.83
170	1912.8	0.9354	0.008312	101.00	0.69585	70.28	7.26	63.02	0.7754	81.27
180	2367.2	0.9224	0.01020	103.97	0.66150	68.77	7.31	61.46	0.7566	81.24
190	2899.4	0.9091	0.01240	106.80	0.63023	67.31	7.34	59.97	0.7373	81.34
200	3518.3	0.8955	0.01500	109.08	0.60183	65.65	7.34	58.31	0.7173	81.29
210	4233.0	0.8802	0.01798	111.36	0.57607	64.15	7.34	56.81	0.6964	81.58
220	5053.8	0.8672	0.02145	113.27	0.55273	62.60	7.31	55.29	0.6757	81.82
230	5991.8	0.8518	0.02544	114.92	0.53164	61.10	7.27	53.83	0.6538	82.33
240	7059.6	0.8356	0.03000	116.36	0.51263	59.65	7.22	52.43	0.6312	83.06)
250	8270.5	0.8196	0.0354	116.92	0.49553	57.93	7.12	50.81	0.6075	83.64)
260	9639.8	0.8016	0.0417	116.74	0.48021	56.06	6.97	49.09	0.5821	84.33)
270	11185.0	0.7834	0.0492	115.64	0.46653	53.95	6.78	47.17	0.5554	84.93)

TABLE 14

Brom-benzene

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p.\Delta v.T}{10^6}$	A	Latent heat	E_1	$L-E_1$	$d^{1/3}-D^{1/3}$	$\frac{L-E_1}{d^{1/3}-D^{1/3}}$
30°	5.67	1.4815	0.00004702	36.54	1.87985	68.68	3.84	64.84	1.1039	58.74)
100	141.23	1.3864	0.0009519	55.30	1.13159	62.58	4.72	57.86	1.0166	56.93
160	840.81	1.2994	0.005255	68.99	0.79276	54.69	5.07	49.62	0.9174	54.09)
170	1071.6	1.2847	0.006553	72.06	0.75220	54.21	5.18	49.03	0.9000	54.48)
180	1349.3	1.2697	0.008071	75.24	0.71501	53.80	5.29	48.51	0.8822	54.98
190	1679.9	1.2534	0.009911	77.88	0.68085	53.02	5.35	47.67	0.8634	55.21
200	2070.1	1.2385	0.01205	80.49	0.64942	52.27	5.42	46.85	0.8447	55.45
210	2527.0	1.2210	0.01450	83.18	0.62046	51.61	5.48	46.13	0.8250	55.91
220	3057.8	1.2037	0.01750	84.90	0.59370	50.48	5.48	44.93	0.8041	55.87
230	3670.2	1.1876	0.02080	87.21	0.56895	49.62	5.52	44.10	0.7840	56.25
240	4372.5	1.1689	0.02482	88.45	0.54600	48.29	5.49	42.80	0.7617	56.19
250	5173.0	1.1510	0.02927	90.06	0.52467	47.25	5.48	41.77	0.7398	56.44
260	6080.8	1.1310	0.03427	91.72	0.50483	46.30	5.48	40.82	0.7171	56.92
270	7104.8	1.1099	0.04016	92.59	0.48632	45 03	5.43	39.60	0.6929	57.15

TABLE 15

Iodo-benzene

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p.\Delta v.T}{10^6}$	A	Latent heat	E_1	$L-E_1$	$d^{1/3}-D^{1/3}$	$\frac{L-E_1}{d^{1/3}-D^{1/3}}$
30°	1.48	1.8149	0.00001595	28.11	2.0170	56.70	2.95	53.75	1.1946	44.99
100	50.23	1.7079	0.0004400	42.57	1.2612	53.68	3.62	50.06	1.1193	44.65
190	787.88	1.5627	0.006020	60.37	0.74721	45.11	4.14	40.97	0.9785	41.87)
200	990.60	1.5470	0.007315	63.77	0.71100	45.34	4.28	41.06	0.9624	42.66)
210	1232.0	1.5316	0.008889	66.51	0.67797	45.10	4.38	40 72	0.9456	43.06)
220	1517.1	1.5115	0.01070	69.37	0.64792	44.94	4.47	40.47	0.9272	43.64
230	1851.5	1.4941	0.01296	71.25	0.62066	44.22	4.50	39.72	0.9083	43.73
240	2241.2	1.4764	0.01552	73.32	0.59602	43.70	4.54	39.16	0.8893	44.03
250	2693.2	1.4581	0.01849	75.20	0.57374	43.15	4.56	38.59	0.8695	44.38
260	3214.9	1.4384	0.02199	76.71	0.55395	42.50	4.57	37.93	0.8486	44.68
270	3815.0	1.4172	0.02605	78.06	0.53614	41.85	4.56	37.29	0.8268	45.10

TABLE 16

Carbon Tetrachloride

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p.\Delta v.T.}{10^6}$	A	Latent heat	E_1	$L - E_1$	$d^{1/3}-D^{1/3}$	$\frac{L-E_1}{d^{1/3}-D^{1/3}}$
0°	33.08	1.6327	0.0002984	30.27	1.7135	51.87	3.52	48.35	1.1107	43.53
90	1117.0	1.4554	0.007974	50.56	0.89103	45.05	4.43	40.62	0.9334	43.52
100	1464.8	1.4343	0.01026	52.89	0.83580	44.20	4.52	39.68	0.9105	43.58
110	1889.4	1.4124	0.01304	54.99	0.78563	43.21	4.57	38.64	0.8866	43.58
120	2400.8	1.3902	0.01634	57.08	0.73997	42 24	4.61	37.63	0.8623	43.64
130	3009.1	1.3680	0.02024	59.05	0.69855	41.25	4.67	36.58	0.8376	43.67
140	3725.1	1.3450	0.02481	60.92	0.66093	40.26	4.70	35.56	0.8121	43.79
150	4559.6	1.3215	0.03021	62.37	0.62679	39.09	4.67	34.42	0.7860	43.79
160	5524.6	1.2982	0.03650	63.70	0.59581	37.95	4.67	33.28	0.7592	43.83
170	6631.9	1.2734	0.04386	64.66	0.56775	36.71	4.64	32.07	0.7312	43.86
180	7894.8	1.2470	0.05249	65.27	0.54234	35.40	4.57	30.83	0.7020	43.92
190	9326.7	1.2192	0.06250	65.55	0.51927	34.04	4.52	29.52	0.6714	44.00
200	10943.0	1.1888	0.07418	65.42	0.49841	32.61	4.39	28.22	0.6391	44.16
210	12759.0	1.1566	0.08787	64.83	0.47957	31.09	4.26	26.83	0.6051	44.34
220	14793.0	1.1227	0.1040	63.67	0.46257	29.45	4.10	25.35	0.5690	44.55
230	17066.0	1.0857	0.1232	61.80	0.44722	27.64	3.91	23.73	0.5301	44.76
240	19596.0	1.0444	0.1464	59.01	0.43338	25.56	3.65	21.91	0.4875	44.94
250	22490.0	0.9980	0.1754	55.08	0.42093	23.19	3.34	19.85	0.4395	45.16
260	25532.0	0.9409	0.2146	48.99	0.40973	20.07	2.92	17.15	0.3812	44.99
270	28992.0	0.8666	0.2710	39.92	0.39971	15.96	2.34	13.62	0.3063	44.47
280	32825.0	0.7634	0.3597	26.68	0.39071	10.43	1.53	8.90	0.2027	43.90

TABLE 17

Stannic Chloride

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p.\Delta v.T}{10^6}$	A	Latent heat	E_1	$L - E_1$	$d^{1/3}-D^{1/3}$	$\frac{L-E_1}{d^{1/3}-D^{1/3}}$
0°	5.88	2.2789	0.00008996	17.84	1.98373	35.38	2.08	33.30	1.2711	26.20
100	498.5	2.0186	0.005764	31.89	0.98455	31.40	2.72	28.68	1.0845	26.45
110	672.7	1.9916	0.007634	33.24	0.92427	30.72	2.76	27.96	1.0612	26.34
120	891.4	1.9639	0.009940	34.54	0.86900	30.02	2.80	27.22	1.0373	26.24
130	1162.0	1.9357	0.01276	35.82	0.81835	29.32	2.83	26.49	1.0126	26.16
140	1491.0	1.9073	0.01616	36.95	0.77193	28.52	2.85	25.67	0.9873	26.00
150	1888.0	1.8772	0.02024	37.93	0.72941	27.67	2.85	24.82	0.9611	25.82
160	2359.0	1.8481	0.02506	38.92	0.69047	26.86	2.86	24.00	0.9345	25.68
170	2914.0	1.8182	0.03077	39.63	0.65482	25.95	2.85	23.10	0.9071	25.46
180	3561.0	1.7873	0.03759	40.00	0.62219	24.89	2.81	22.08	0.8786	25.13
190	4309.0	1.7556	0.04545	40.30	0.59234	23.87	2.77	21.10	0.8494	24.84)
200	5168.0	1.7224	0.05450	40.65	0.56504	22.97	2.74	20.23	0.8195	24.68)
210	6147.0	1.6866	0.06502	40.64	0.54009	21.95	2.68	19.27	0.7882	24.45)
220	7257.0	1.6488	0.07728	40.39	0.51730	20.89	2.61	18.28	0.7554	24.20)
230	8509.0	1.6090	0.09149	39.89	0.49648	19.80	2,52	17.28	0.7212	23.96)
240	9915.0	1.5667	0.1083	38.96	0.47748	18.60	2.42	16.18	0.6847	23.63)
250	11488.0	1.5221	0.1280	37.79	0.46016	17.39	2.30	15.09	0.6463	23.35)
260	13242.0	1.4747	0.1520	36.07	0.44438	16.03	2.15	13.88	0.6045	22.96)
270	15190.0	1.4219	0.1812	33.82	0.43001	14.54	1.98	12.56	0.5586	22.47)
280	17351.0	1.3628	0.2160	31.38	0.41694	13.08	1.81	11.27	0.5087	22.15)

TABLE 18

Water

Temperature	Pressure	Density of liquid	Density of vapor	Latent heat	E_1	$L - E_1$	$d^{\frac{1}{3}} - D^{\frac{1}{3}}$	$\frac{L - E_1}{d^{\frac{1}{3}} - D^{\frac{1}{3}}}$
0°	4.569	0.9999	0.000004737	606.5	30.7	575.8	0.9831	585.7)
10	9.140	0.9997	0.000009200	599.5	31.6	567.9	0.9790	580.1)
20	17.363	0.9982	0.00001699	592.6	32.5	560.1	0.9737	575.2)
30	31.510	0.9957	0.00002995	585.7	33.5	552.2	0.9675	570.7)
40	54,865	0.9923	0.00005071	578.6	34.4	544.2	0.9604	566.6
50	91.978	0.9881	0.00008278	571.6	35.4	536.2	0.9524	563.0
60	148.885	0.9833	0.0001303	564.7	36.3	528.4	0.9437	559.9
70	233.308	0.9779	0.0001989	557.6	37.3	520.3	0.9342	556.9
80	354.873	0.9719	0.0002952	550.6	38.2	512.4	0.9240	554.5
90	525.468	0.9655	0.0004273	543.5	39.1	504.4	0.9131	552.4
100	760.000	0.9586	0.0006031	536.5	40.1	496.4	0.9015	550.6
110	1075.37	0.9512	0.0008389	529.4	40.8	488.6	0.8892	549.5
120	1484.0	0.9441	0.001138	522.3	41.4	480.9	0.8766	548.6
130	2019.0	0.9365	0.001522	515.1	42.1	473.0	0.8634	547.8
140	2694.0	0.9283	0.002000	508.0	42.8	465.2	0.8495	547.6
150	3568.0	0.9193	0.002592	500.7	43.7	457.0	0.8349	547.3
160	4652.0	0.9095	0.003313	493.6	44.5	449.1	0.8198	547.8
170	5937.0	0.8989	0.004181	486.2	45.0	441.2	0.8040	548.7
180	7487.0	0.8881	0.005216	479.0	45.4	433.6	0.7878	550.4
190	9403.0	0.8766	0.006439	471.6	46.1	425.5	0.7711	551.8
200	11625.0	0.8646	0.007855	464.3	46.7	417.6	0.7539	553.9
210	14240.0	0.8523	0.009506	456.8	47.1	409.7	0.7363	556.4
220	17365.0	0.8393	0.01140	449.4	47.8	401.6	0.7182	559.1
230	20936.0	0.8256	0.01369	441.9	48.4	393.5	0.6989	563.0
240	25019.0	0.8117	0.01632	423.8	47.8	376.0	0.6791	553.6
250	29734.0	0.7980	0.01944	410.4	47.5	362.9	0.6586	551.0
260	35059.0	0.7840	0.02315	394.0	46.8	347.2	0.6371	544.9
270	41101.0	0.7701	0.02766	374,5	45.6	328.9	0.6142	535.5)

TABLE 19

Methyl Alcohol

Temperature	Pressure	Density of liquid	Density of vapor	Latent heat	E_1	$L - E_1$	$d^{\frac{1}{3}} - D^{\frac{1}{3}}$	$\frac{L - E_1}{d^{\frac{1}{3}} - D^{\frac{1}{3}}}$
0°	29.6	0.8101	0.00005620	289.17	16.77	272.40	0.8939	304.7
10	54.7	0.8000	0.00009960	287.36	17.48	269.88	0,8819	306.0
20	96.0	0.7905	0.0001695	284.54	18.03	266.51	0.8692	306.6
30	160.0	0.7830	0.0002772	282.07	18.37	263.70	0.8565	307.9
40	260.5	0.7745	0.0004394	277.78	18.87	258.91	0.8423	307.4
50	406.0	0.7650	0.0006739	274.14	19.16	254.98	0.8269	308.3
60	625.0	0.7555	0.001006	269.41	19.75	249.66	0.8106	308.0
70	926.6	0.7460	0.001465	264.51	20.10	244.41	0.7933	308.1
80	1341.0	0.7355	0.002084	258.96	20.43	238.53	0.7750	307.8
90	1897.0	0.7250	0.002907	252.76	20.70	232.06	0.7557	307.1
100	2621.0	0.7140	0.003984	246.01	20.82	225.19	0.7353	306.3
110	3561.0	0.7020	0.005376	239.27	20.92	218.35	0.7135	306.0
120	4751.0	0.6900	0.007142	232.00	20.95	211.05	0.6911	305.4
130	6242.0	0.6770	0.009379	224.07	20.88	203.19	0.6672	304.5
140	8071.0	0.6640	0.01216	216.12	20.74	195.38	0.6424	304.1
150	10336.0	0.6495	0.01562	206.13	20.55	185.58	0.6160	301.3
160	13027.0	0.6340	0.01994	198.34	20.15	178.19	0.5879	303.1
170	16292.0	0.6160	0.02526	188.25	19.70	168.55	0.5575	302.3
180	20089.0	0.5980	0.03186	177.16	19.01	158.15	0.5255	300.9
190	24615.0	0.5770	0.04010	165.64	18.18	147.46	0.4902	300.8
200	29787.0	0.5530	0.05075	151 84	16.97	134.87	0.4506	299.3
210	35770.0	0.5255	0.06521	134.78	15.29	119.49	0.4045	295.4)
220	42573.0	0.4900	0.08635	112.53	12.92	99.61	0.3464	287.6)
225	46297.0	0 4675	0.1003	99.50	11.54	87.96	0.3114	282 4)
230	50414.0	0.4410	0.1187	84.47	9.87	74.60	0.2697	276.5)
232	52202.0	0.4295	0.1277	77.73	9.14	68.59	0.2509	273.4)
234	53939.0	0.4145	0.1381	70.15	8.29	61.86	0.2287	270.5)
236	55624.0	0.3955	0.1505	61.66	7.27	54.39	0.2020	269.2)
238	57576.0	0.3705	0.1681	50.22	5.96	44.26	0.1663	266.1)
238.5	58329.0	0.3635	0.1789	44.23	5.27	38.96	0.1502	259.4)

TABLE 20

Ethyl Alcohol

Temperature	Pressure	Density of liquid	Density of vapor	Latent heat	E_1	$L-E_1$	$d^{1/3}-D^{1/3}$	$\frac{L-E_1}{d^{1/3}-D^{1/3}}$
0°	12.24	0.8062	0.00003300	220.9	11.7	209.2	0.8986	232.8)
10	23.73	0.7979	0.00006207	221.2	12.2	209.0	0.8879	235.4
20	43.97	0.7894	0.0001110	220.6	12.6	208.0	0.8761	237.4
30	78.11	0,7810	0.0001910	220.1	13.0	207.1	0.8633	239.9
40	133.42	0.7722	0.0003150	218.7	13.4	205.3	0.8494	241.7
50	219.82	0.7633	0.0005060	216.0	13.8	202.2	0.8342	242.4
60	350.21	0.7541	0.0007900	213.4	14.2	199.2	0.8178	243.6
70	540.91	0.7446	0.001190	209.9	14.5	195.4	0.8004	244.1
80	811.81	0.7348	0.001740	206.4	14.8	191.6	0.7821	244.9
90	1186.5	0.7251	0.002500	201.6	15.0	186.6	0.7627	244.6
100	1692.3	0.7157	0.003510	197.1	15.3	181.8	0.7425	244.8
110	2359.8	0.7057	0.004860	190.3	15.4	174.9	0.7209	242.7
120	3223.0	0.6925	0.006580	184.2	15.4	168.8	0.6973	242.1
130	4318.7	0.6789	0.008770	177.6	15.5	162.1	0.6727	241.0
140	5686.6	0.6631	0.01152	171.1	15.4	155.7	0.6461	241.0
150	7368.7	0.6489	0.01488	164.7	15.4	149.3	0.6198	241.1
160	9409.9	0.6329	0.01916	156.9	15.2	141.7	0.5910	239.8
170	11858.0	0.6165	0.02446	148.4	14.8	133.6	0.5608	238.2
180	14767.0	0.5984	0.03115	139.2	14.3	124.9	0.5281	236.5
190	18185.0	0.5782	0.03970	128.4	13.6	114.8	0.4919	233.3)
200	22182.0	0.5568	0.05080	116.6	12.6	104.0	0.4523	230.0)
210	26825.0	0.5291	0.06550	103.2	11.4	91.8	0.4057	226.3)
220	32196.0	0.4958	0.08540	88.2	9.9	78.3	0.3511	223.0)
230	38389.0	0.4550	0.1135	70.6	8 1	62.5	0.2849	219.7)
240	45519.0	0.3825	0.1715	40.3	4.7	35.6	0.1703	209.2)
241	46288.0	0.3705	0.1835	35.0	4.0	31.0	0.1499	206.8)
242	47069.0	3.3546	0.1990	28.4	3.3	25.1	0.1239	202.6)
242.5	47463.0	0.3419	0.2164	22.1	2.6	19.5	0.0989	197.2)

TABLE 21

Propyl Alcohol

Temperature	Pressure	Density of liquid	Density of vapor	Latent heat	E_1	$L-E_1$	$d^{1/3}-D^{1/3}$	$\frac{L-E_1}{d^{1/3}-D^{1/3}}$
0°	3.44	0.8193	0.00001212	104.4	9.0	185.4	0.9127	203.1
80	376.0	0.7520	0.00104	173.0	11.4	161.5	0.8081	199.9
90	574.0	0.7425	0.00156	169.0	11.7	157.3	0.7895	199.2
100	842.5	0 7325	0.00226	164.0	11.8	152.2	0.7702	197.6
110	1206.0	0.7220	0 00320	159.0	11.9	147.1	0.7497	196.2
120	1683.0	0.7110	0.00443	153.0	12.0	141.0	0.7284	193.6)
130	2293.0	0.6995	0.00605	147.0	12.0	135.0	0.7055	191.3)
140	3074.0	0.6875	0.00805	142.4	12.0	130.4	0.6822	191.1)
150	4052.0	0.6740	0.01060	135.3	11.9	123.4	0.6571	187.8)
160	5264.0	0.6600	0.01380	129.0	11.9	117.1	0.6308	185.6)
170	6695.0	0.6450	0.01770	122.8	11.7	111.1	0.6034	184.1)
180	8383.0	0.6285	0.0225	116.3	11.4	104.9	0.5743	182.7)
190	10466.0	0.6110	0.0282	109.6	11.4	98.2	0.5442	180.4)
200	12801.0	0.5920	0.0353	102.2	10.8	91.4	0.5117	178.6)
210	15575.0	0.5715	0.0442	94.5	10.4	84.1	0.4763	176.6)
220	18679.0	0.5485	0.0556	85.3	9.6	75.7	0.4369	173.2)
230	22154.0	0.5230	0.0704	75.0	8.7	66.3	0.3927	168.8)
240	26194.0	0.4920	0.0904	63.4	7.5	55.9	0.3406	164.1)
250	30785.0	0.4525	0.1180	50.6	6.2	44.4	0.2772	160.2)
260	36103.0	0.3905	0.1610	33.5	4.2	29.3	0.1868	157.0)

TABLE 22

Acetic Acid

Temperature	Pressure	Density of liquid	Density of vapor	$\frac{p.\Delta v.T}{10^6}$	A	Latent heat	E_1	$L - E_1$	$d^{1/8}-D^{1/8}$	$\frac{L-E_1}{d^{1/8}-D^{1/8}}$
20°	11.73	1.0491	0.00007645	--------	----------	84.05	4.88	79.17	0.9737	81.3
30	20.61	1.0392	0.0001264	--------	----------	85.88	5.19	80.69	0.9627	83.8
40	34.77	1.0284	0.0002012	--------	----------	87.02	5.17	81.85	0.9507	86.1
50	56.56	1.0175	0.0003100	--------	----------	88.14	5.81	82.33	0.9381	87.8
60	88.94	1.0060	0.0004621	--------	----------	89.69	6.12	83.57	0.9247	90.4
40	136.0	0.9948	0.0006729	--------	----------	90.43	6.43	84.00	0.9107	92.2
80	202.3	0.9835	0.0009588	--------	----------	91.59	6.71	84.88	0.8959	94.7
90	293.7	0.9718	0.001338	--------	----------	91.88	6.98	84.90	0.8803	96.4
100	417.1	0.9599	0.001833	--------	----------	92.32	7.23	85.09	0.8641	98.5
110	580.8	0.9483	0.002468	--------	----------	92.79	7.47	85.32	0.8474	100.7
120	804.0	0.9362	0.003271	96,24	0.98068	94.38	7.79	86.59	0.8298	104.3
130	1083.0	0.9225	0.004275	101.60	0.91636	93.11	8.02	85.09	0.8112	104.9
140	1431.0	0.9091	0.005516	106.51	0.86227	91.83	8.21	83.62	0.7920	105.5
150	1863.0	0.8961	0.007032	111.21	0.81598	90.74	8.37	82.37	0.7725	106.6
160	2392.0	0.8818	0.008873	115.57	0.77567	89.63	8.49	81.14	0.7519	107.9
170	3034.0	0.8688	0.01084	122.49	0.74002	90.65	8.80	81.85	0.7329	111.7
180	3809.0	0.8554	0.01370	123.89	0.70709	87.71	8,70	79.01	0.7100	111.3
190	4735.0	0.8417	0.01681	127.79	0.67885	86.75	8.78	77.97	0.6880	113.3
200	5836.0	0.8264	0.02052	131.21	0.65202	85.55	8.83	76.72	0.6646	115.4
210	7134.0	0.8117	0.02488	134.23	0.62709	84.17	8.85	75.32	0.6409	117.5
220	8655.0	0.7943	0.03021	135.87	0.60374	82.02	7.77	73.25	0.6147	119.1
230	10426.0	0.7758	0.03626	137.82	0.58171	80.16	8.72	71.44	0.5879	121.5
240	12475.0	0.7576	0.04327	139.43	0.56084	78.18	8.64	69.54	0.5605	124.1
250	14832.0	0.7358	0.05163	139.69	0.54097	75.55	8.50	67.05	0.5304	126.4
260	17527.0	0.7138	0.06165	138.42	0.52199	72.26	8.26	64.00	0.4986	128.4
270	20590.0	0.6896	0.07364	135.64	0.50381	68.33	7.95	60.37	0.4643	130.0
280	24055.0	0.6596	0.08834	130.33	0.48637	63.39	7.50	55.89	0.4251	131.5
290	27951.0	0.6337	0.1073	121.83	0.46963	57.21	6.89	50.32	0.3837	131.2
300	32312.0	0.5956	0.1331	107.95	0.45350	48.95	6.00	42.95	0.3308	126.8
310	37168.0	0.5423	0.1718	86.23	0.43798	37.77	4.71	33.06	0.2595	127.4
320	42550.0	0.4615	0.2591	42,64	0.42301	18.04	2.29	15.75	0.1353	116.4

VOL. XX DEC. 1904 NO. 4

JOURNAL

OF THE

Elisha Mitchell Scientific Society

(Official Publication of the N. C. Academy of Science)

ISSUED QUARTERLY

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TO BE ENTERED AT THE POSTOFFICE AS SECOND CLASS MATTER

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Journal of the Elisha Mitchell Scientific Society—Quarterly. Price $2.00 per year; single numbers 50 cents. Most numbers of former volumes can be supplied. Direct all correspondence to the Editors, at University of North Carolina, Chapel Hill, N. C.

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A. S. WHEELER, Rec. Sec. F. P. VENABLE, Perm. Sec.

EDITORS OF THE JOURNAL:

W. C. COKER,

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PROCEEDINGS OF THE THIRD ANNUAL MEETING
OF THE
NORTH CAROLINA ACADEMY OF SCIENCE
HELD AT
WAKE FOREST, N. C., MAY 13-14, 1904.

FRIDAY AFTERNOON SESSION.

The meeting was called to order in Lea Laboratory at 3 P. M. by the President, Dr. Chas. Baskerville, who at once appointed the following Nominating Cnmmittee: Messrs. Tait Butler, W. C. Coker and W. L. Poteat.

The Executive Committee had previously elected Dr. F. L. Stevens Vice-President for the present meeting to fill the vacancy caused by the removal from the State of Dr. J. I. Hamaker.

Dr. Baskerville explained delay in the distribution of the last issue of THE JOURNAL containing proceedings of the previous meeting, after which the Academy proceeded at once to the presentation of the following papers:

1. FERTILIZATION OF ALBUGO IPOMOEA PANDURATA:

F. L. Stevens.

This fungous is multinucleate. The nuclei pass through two mitotic divisions as in other species of the genus. During these divisions all of the nuclei, except one,

[Issued January 28th, 1905.]

pass to the periplasm. One nuclus is retained by the coenocentrum. The fertilization is simple, therefore, and not multiple as in some other species. Minor peculiarities concerning the formation of the walls and development of the coenocentrum, etc., were described.

2. FORECASTS OF THE SKY, OR, EXPECTED NOTABLE OBJECTS: *Jno. F. Lanneau.*

3. A LIRIODENDRON FROM THE DEEP RIVER TRIASSIC: *Collier Cobb.*

The tulip tree is the lone survivor of an ancient race known to extend back into Cretaceous time, from which time its family history has been traced, and "we find this history epitomised in the existing species". Holm considers the primitive ancestral type of Liriodendron to have been a simple, magnolia-like leaf; for not only do all modern relatives of Liridodendron have such leaves, but "there is a progressive simplification and reduction in lobation as we proceed back in time, the most primitive forms known having ovate or oblong simple leaves". The youngest leaves on our modern tulip trees are entire or merely slightly notched, while the mature ones are typically lobed leaves. Hence it is imagined that the primitive tulip tree that grew in early Cretaceous or Jura-Cretaceous time had simple ovate or lanceolate leaves, short petioled and without stipules or bud scales, and with venation much like the existing magnolia leaf. The leaf here presented has the lobate form common in the American Cretaceous, when the modern form is supposed to have become practically fixed in *L. oblongifolium* of the Amboy clays. But this specimen came from the light brown shales of the Deep River Triassic at Cumnock (Egypt), and is found in association with *Macrotaeniopteris magnifolia*, somewhat common in the Triassic coal measures of Virginia, and *Taeniopteris Newberriana*, a well-marked Permian plant. The chief interest in the finding of this plant in the Deep River beds, probably near the base of the Triassic, lies in the fact that it is the mature form of leaf, and that we must look still farther back in geological time for the simple ovate form.

4. ANGIOSPERMS WITH EXPOSED OVULES: *W. C. Coker.*

Attention was called to some Angiosperms in which the carpels are not completely fused, so that the seeds are exposed directly to the air. In Tiarella the two carpels, which are of unequal size, are not fused even in the flower and the air has full access to the ovules at the time of fertilization. Fruits of Sterculia platani folia were shown with open carpels and the unripe seeds completely exposed. In Cuphea the central placenta bursts and ruptures the wall of the capsule, exposing the seeds sometime before they are ripe.

5. WORKING UP THE ENTOMOLOGICAL FAUNA OF NORTH CAROLINA: *Franklin Sherman, Jr., and C. S. Brimley.*

(Appears in full in this issue.)

6. SOLUTION OF A NEW MATHEMATICAL CURVE: *Jas. L. Lake.*

7. CLEISTOGAMIC PLANTS: *W. C. Coker.*

The frequent occurrence of cleistogamy was pointed out, and the results of a study of the cleistogamic flowers of Specularia perfoliata and Lamium amplexicaule were presented.

8. REPORT,—RECENT SOIL WORK: *W. G. Morrison.*

The following were presented by title only, the author being absent:

9. FURTHER NOTES ON THE REPRODUCTION OF REPTILES: *C. S. Brimley.*

(Appears in full in this issue.)

10. A CASE OF SNAKE-BITE, BY THE VICTIM: *C. S. Brimley.*

(Appears in full in this issue.)

11. NOTES ON REARING MOTHS FROM THE LARVAE:

C. S. Brimley.

The experience of several years shows that caterpillars of moths, such as the Grape Sphinx (Ampelophaga myron) and the Ash Sphinx (Ceratomia undulosa), whose food is not succulent, may be more easily reared in closed jars than those which feed on succulent leaves, such as Tomato Worms (Phlegethontius Carolina). Hawk moths are often attacked and killed both by Braconid flies and Tachina flies. The large Sphinx of the grape (Pholus pandorus) is even more persecuted by these parasites, and the Tomato Worm is much troubled by the Braconids. The common Ash Sphinx (Ceratomia undulosa) and Grape Sphinx (Ampelophaga myron), however, are seldom molested. Five larvae of the Myron Sphinx of the grape obtained in August all transformed into pupae on consecutive days; two of these produced moths in about sixteen days after transforming; the other three overwintered; two of the latter died, but the third produced a moth almost exactly nine months after it had pupated—taking about fourteen times as long to emerge as the first two. Tomato Worms and some other insects show similar peculiarities in pupation.

NIGHT SESSION.

The night session of the Academy was held in Leigh Hall. The address of welcome was made by Prof. Jno. F. Lanneau and the response by Prof. Collier Cobb. Dr. Baskerville, President of the Academy, then gave his retiring address, the subject being: "*Science and the People.*" At the conclusion of the address the Academy was tendered an informal reception by the ladies and faculty of Wake Forest College.

SATURDAY MORNING SESSION.

The Academy was called to order by President Baskerville and proceeded at once to the presentation of papers, as follows:

12. THE ELECTRONIC THEORY (by title): *C. W. Edwards.*

13. THE PHENOMENA OF FEVER: *Fred. K. Cooke.*

14. ON SEEING THE RED CORPUSCLES IN ONE'S OWN BLOOD: *W. L. Poteat.*

The paper gave in outline a research upon the numerous vaguely bright little discs which pass quickly across the field of vision in all directions when the eye is turned toward a uniformally illuminated surface, as the sky. These bodies are clearly distinguishable from the *muscæ volitantes* and were shown to be the red corpuscles floating in the capillary vessels of the outer layers of the retina in the region of the *macula lutea.* Certain streams of the little bodies were definitely located in the field of vision for each eye. Then the distribution of the blood vessels in the macular region was mapped. In position in the field of vision, as well as in their relation to one another, the vessels and the streams of discs coincided precisely. [So much had been previously observed, first apparently by Vierordt as early as 1856 and afterwards by Professor Rood, Johannes Müller, Helmholtz, and others.] It remained to discover some means of superimposing the two systems upon one another, or of so projecting them as to see streaming discs and branching vessels at the same time. This was done successfully in this way; Through a pin-hole in a card revolved eccentrically a certain vessel projected against the flat flame of an ordinary lamp was localized as passing through the central prominence of the flame. Then with the eye stationary the pin-hole was slowly moved so that the designated vessel could be seen just past the edge of the hole; whereupon the discs (red corpuscles) were plainly visible moving within the walls of the vessel.

15. INACTIVE THORIUM: *Fritz Zerban.*

The paper gives first a brief account of the discovery of radio active substances, of their properties and of the methods for determining and measuring radio activity. Special attention is given to thorium, the radio activity of which was discovered by G. C. Schmidt and Mme. Curie. The question, whether thorium is primarily radio active or whether its activity is due to the admixture of other radio active substances, is treated. The work carried out by Rutherford and his co-laborers on this subject is briefly stated. While these investigations were made with commercial thorium without regard to its source, Hofmann and Zerban paid strict attention to the latter. From observations made with thorium from all the important thorium minerals the conclusion is drawn that thorium itself possesses no primary radio activity.

16. THORIUM, CAROLINIUM AND BERZELIUM:

Chas. Baskerville.

This paper presents a brief historical account of the discovery of thorium and the questions raised as to its elementary character. The published evidence is considered in conjunction with experimental data obtained, and the conclusions arrived at that thorium is not a primary radio active body. The complex nature of thorium is proved by the conduct of salts with certain organic bases, as phenylhydrazine, for example. Fractions were added giving atomic weights from 212 to 252, the original being 232.5. Pure thorium oxide from several sources was converted into the chloride by heating it, mixed with pure sugar carbon within quart tubes, during the passage of dry chlorine. A volatile chloride, "weisser dampff" of Berzelius, was obtained, decreasing in amount according to the duration and temperature of the reaction. The purified, delicately green oxide obtained from this gave a specific gravity of 8.47 and the element berezelium an atomic weight of 212 (tetrad). The temperature of the tube was raised and thorium tetrachloride distilled away. The residue in the carbon boat on purification gave a greyish pink oxide with a specific gravity of 11.26 and an atomic weight of (tetrad) 255.6 (carolinium). The new thorium, or that in a large measure freed from the berezelium and carolinium, gave an atomic weight of 220.6, and a white oxide with a specific gravity of 9.2. The original thorium gave atomic weights 232.5 to 232.6, and its oxide had a specific gravity of 10.5. The original thorium dioxide phosphoresces under the influence of ultra violet light, as does zirconium dioxide. Berzelium and carolinium oxides do not respond to this stimulus, while the new thorium glows with increasing luminosity according to the decrease of the novel substances. All these bodies are radio active. Certain chemical differences are noted, as, for example, the conduct of their salts with organic bases, fumaric acid, &c. Carolinium oxide is soluble in concentrated hydrochlroric acid, while berzelium and carolinium oxides are not. Spectral data are wanting; in fact, the limited portions of the spectra (arc and spark) mapped show the bodies identical. The materials are not yet sufficiently pure, nor the spectral data sufficiently complete, to warrant final acceptance, although the preponderance of evidence is favorable to the assumption of the existence of two new members of the family of chemical elements. *

BUSINESS MEETING.

The Academy was called to order at 12:30 P. M. by President Baskerville.

Prof. Poteat urged a continuance of a joint meeting of the Academy with the Chemical Section, and presented the following resolution:

"That the Academy reaffirm its desire that the scientific societies and clubs of the State should hold each one session a year in connection with the annual session of the Academy." *Carried.*

Secretary reported the election to membership of Messrs William B. Streeter and W. C. A. Hammel, of Greensboro.

On recommendation of the Nominating Committee the following officers were elected for the ensuing year:

President, F. L. STEVENS, Raleigh.
Vice-President, JNO. F. LANNEAU, Wake Forest.
Secretary-Treasurer, FRANKLIN SHERMAN, JR., Raleigh.

Executive Committee:—President and Secretary ex officio, CHAS. BASKERVILLE, Chapel Hill; C. W. EDWARDS, Durham; T. GILBERT PEARSON, Greensboro.

On motion it was resolved:

That the North Carolina Academy of Science and the North Carolina Section of the American Chemical Society do hereby express their pleasure and gratitude to the faculty and ladies of Wake Forest College for the facilities placed at their disposal and for the warm hospitality which they have shown at this, their first joint gathering.

Secretary's report was then presented showing a total membership of forty-seven, embracing practically every branch of science represented in the State.

Treasurer's report sdowed a balance of $108.55 on hand.

Prof. Pearson extended an invitation to the Academy to hold the next annual meeting at Greensboro. By motion it was resolved to be the sense of the Academy that the next meeting should be at Greensboro. During the meeting twenty-four persons were in attendance.

The Academy then adjourned.

LIST OF MEMBERS AND ASSOCIATE MEMBERS.

Andrews, W. J., Raleigh.
Ashe, W. W., Raleigh.
Baskerville, Chas., Chapel Hill (removed).
Battle, K. P., Raleigh.
Beardslee, Henry C., Asheville.
Binford, Raymond, Guilford College.
Brewer, Chas. E., Wake Forest.
Brimley, C. S., Raleigh.
Brimley, H. H., Raleigh.
Butler, Tait, Raleigh.
Burkett, Chas., Raleigh.
Cain, Wm., Chapel Hill.
Chapin, Spencer, Littleton.
Cobb, Collier, Chapel Hill.
Coker, R. E., Beaufort.
Coker, W. C., Chapel Hill.

Cooke, Fred. K., Wake Forest.
Duerden, J. E., Chapel Hill (removed).
Edwards, C. W., Durham.
Garrett, Mrs. R. U., Asheville.
Gore, J. W., Chapel Hill.
Hamaker, J. I., Durham (removed).
Hammel, W. C. A., Greensboro.
Hoffman, S. W., Statesville.
Holmes, Jos. A., Chapel Hill.
Howell, E. V., Chapel Hill.
Kesler, J. L., Raleigh (removed).
Kilgore, B. W., Raleigh.
Lake, Jas. L., Wake Forest.
Lanneau, Jno. F., Wake Forest.
Latta, J. E., Chapel Hill.
Lewis, R. H., Raleigh.
Meade, Miss A. M., Raleigh (removed).
Myers, E. W., Greensboro.
Pearson, T. Gilbert, Greensboro.
Pegram, W. H., Durham.
Poteat, W. L., Wake Forest.
Rankin, W. S., Wake Forest.
Sackett, W. G., Raleigh (removed).
Sherman, Franklin, Jr., Raleigh.
Smith, Henry L., Davidson.
Stevens, F. L., Raleigh.
Stevens, Mrs. F. L., Raleigh.
Streeter, Wm. B., Greensboro.
Venable, F, P., Chapel Hill.
Wheeler, A. S., Chapel Hill.
Williams, C. B , Raleigh.
Wilson, H. V., Chapel Hill.
Wilson, R. N., Guilford College.
Winston, Geo. T., Raleigh.

ON THE GRAPHIC REPRESENTATION
OF THE
PROJECTION OF TWO TRIADS OF PLANES INTO THE MYSTIC HEXAGRAM.

BY ARCHIBALD HENDERSON, PH.D.

WITH PLATE I.

Cayley* has considered the following question: to find a point such that its polar plane in regard to a given system of three planes is the same as its polar plane in regard to another given system of three planes.

Let us designate for convenience the first three planes as *a*, *b*, and *c*, the second three as *f*, *g*, and *h*: The line *ab* will denote the line of intersection of the planes *a* and *b*, and the point *abc* will denote the point of intersection of the planes *a*, *b*, and *c*; and so in other cases.

The conclusion reached (l. c.) is that there are four points 0_1, 0_2, 0_3, and 0_4, which fulfil the required conditions. It was shown, that from any one of the points 0, it is possible to draw

a line meeting the lines $af \times bg \times ch$ [1]
" " $ag \times bh \times cf$ [2]
" " $ah \times bf \times cg$ [3]
" " $af \times bh \times cg$ [4]
" " $ag \times bf \times ch$ [5]
" " $ah \times bg \times cf$ [6]

and moreover that these six lines [1], [2], [3], [4], [5], and [6] lie on a cone of the second order. Projecting now the figure of the six planes *a*, *b*, *c*, *f*, *g*, and *h* upon any arbitrary plane (not passing through one of the lines [1], [2], [3], [4], [5], or [6]), we obtain the Pascal configuration. The twenty points *abc*, *abf*, ... *fgh*, are as follows, viz. (omitting the two points *abc*, *fgh*) the remaining eighteen points are the

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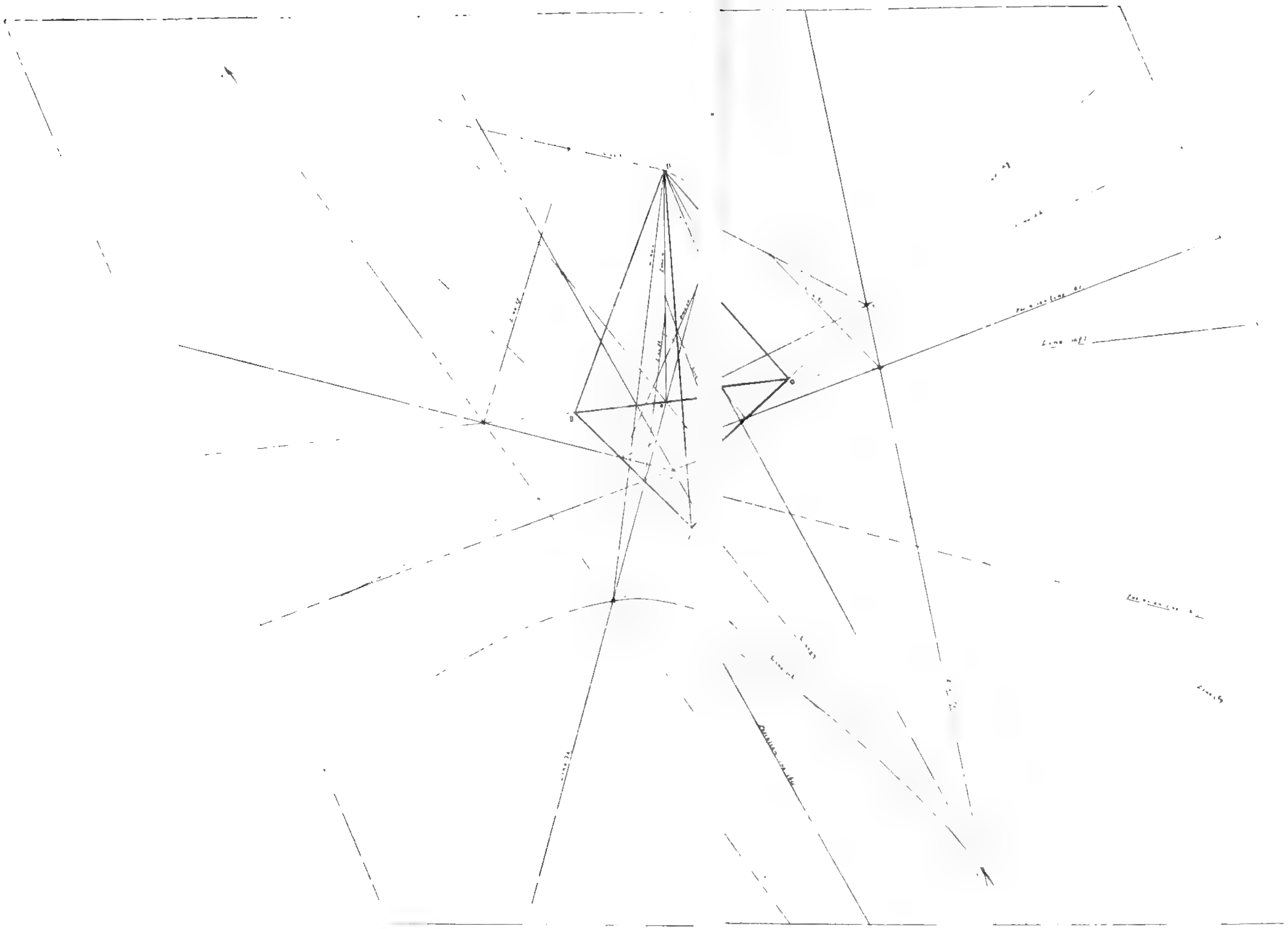
* Collected Math. Papers, Vol. VI., pp. 129-134.

PLATE I.



HENDERSON — GRAPHIC REPRESENTATION.

Pascalian points (the intersections of pairs of lines each through two of the points 1, 2, 3, 4, 5, 6) which lie on the Pascalian lines *bc*, *ca*, *ab*, *gh*, *hf*, *fg* respectively; the point *abc* is the intersection of the Pascalian lines *bc*, *ca*, *ab*, and the point *fgh* is the intersection of the Pascalian lines *gh*, *hf*, *fg*, the points in question being two of the points S (Steiner's twenty points, each the intersection of three Pascalian lines).*

§ 2. The question with which I concern myself in the present paper is:—May such a beautiful theorem be represented to the eye in such a way as to show clearly the entire configuration? After some labor and thought, I am able to answer this question in the affirmative. The accompanying plate (Plate I.), drawn to scale with great precision, repre- the sents ultimate result of the investigation.

The initial problem was so to choose the two triads of planes as to give the point of projection 0 a position that might be readily representable on a diagram, showing also the two triads of planes. Choosing to use quadriplanar co-ordinates, I found it desirable for the point 0 to coincide with one of the four vertices A, B, C, and D of the fundamental tetrahedron ABCD. The point 0 was finally chosen, from various considerations into which I shall not enter at present, to coincide with the vertex D. The question that next presented itself was what plane to choose as the plane of projection. The plane ABC was finally chosen as the most economical position for the plane of projection, as will appear later.

I now proceed to an analysis of the problem. The planes were chosen in the following manner:

$$\begin{array}{ll} a: & w = 0 \\ b: & 256\,x - 384\,y - 96\,z + 459\,w = 0 \\ c: & 96\,x - 64\,y - 256\,z + 153\,w = 0 \end{array}$$

and

$$\begin{array}{ll} f: & 32\,x + 27\,w = 0 \\ g: & 64\,y - 51\,w = 0 \\ h: & 32\,z - 17\,w = 0 \end{array}$$

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*It is to be understood that a point or line and its projection have the same designation, and that the meet of a line such as [1] with the plane of projection is denoted by 1.

The first step is to find the polar planes of a point 0 (x_1, y_1, z_1, w_1) with respect to each one the two triads *abc*, *fgh*, then to identify the equations of these two planes, in order to determine the position of the point 0.

First consider the triad *abc*, given by the equation

$$w\,(256\,x - 384\,y - 96\,z + 459\,w)\,(96\,x - 64\,y - 256\,z + 153\,w) = 0$$

which becomes, on clearing out,

$$\begin{aligned} F\,(x, y, z, w) \equiv\ & 24576\,(x^2 + y^2 + z^2)\,w + 70227\,w^3 - 53248\,xyw \\ & -74752\,xzw + 83232\,x\,w^2 + 104448\,yzw \\ & -88128\,y\,w^2 - 132192\,z\,w^2 = 0 \end{aligned}$$

The polar plane

$$\frac{\delta F}{\delta x_1}\,x + \frac{\delta F}{\delta y_1}\,y + \frac{\delta F}{\delta z_1}\,z + \frac{\delta F}{\delta w_1} = 0$$

of the point (x_1, y_1, z_1, w_1) with respect to this system of three planes is

$$\begin{aligned} & (49152\,x_1 w_1 - 53248\,y_1 w_1 - 74752\,z_1 w_1 + 83232\,w_1^2)\,x \\ + & (49152\,y_1 w_1 - 53248\,x_1 w_1 + 104448\,z_1 w_1 - 88128\,w_1^2)\,y \\ + & (49152\,z_1 w_1 - 74752\,x_1 w_1 + 104448\,y_1 w_1 - 132192\,w_1^2)\,z \\ + & [24576\,(x_1^2 + y_1^2 + z_1^2) + 210681\,w_1^2 - 53248\,x_1 y_1 \\ & - 74752\,x_1 z_1 + 166464\,x_1 w_1 + 104448\,y_1 z_1 - 176256\,y_1 w_1 \\ & - 264384\,z_1 w_1]\,w = 0 \qquad [1] \end{aligned}$$

Also the polar plane

$$\frac{\delta f}{\delta x_1}\,x + \frac{\delta f}{\delta y_1}\,y + \frac{\delta f}{\delta z_1}\,z + \frac{\delta f}{\delta w_1}\,w = 0$$

of the point (x_1, y_1. z_1, w_1) with respect to the system *fgh*, given by the equation

$$(32\,x + 27\,w)\,(64\,y - 51\,w)\,(32\,z - 17\,w) = 0$$

or

$$\begin{aligned} f\,(x, y, z, w) \equiv\ & 65536\,xyz + 55296\,yzw - 52224\,xzw \\ & - 44064\,zw^2 - 34816\,xyw - 29376\,yw^2 \\ & + 27744\,xw^2 + 23409\,w^3 = 0 \end{aligned}$$

is given by the equation

$$
\begin{aligned}
&65536\, y_1 z_1 - 52224\, z_1 w_1 - 34816\, y_1 w_1 + 27744\, w_1^2)\, x \\
&+ (65536\, x_1 z_1 + 55296\, z_1 w_1 - 34816\, x_1 w_1 - 29376\, w_1^2)\, y \\
&+ (65536\, x_1 y_1 + 55296\, y_1 w_1 - 52224\, x_1 w_1 - 44064\, w_1^2)\, z \\
&+ [55296\, y_1 z_1 - 52224\, x_1 z_1 - 88128\, z_1 w_1 - 34816\, x_1 y_1 \\
&\quad - 58752\, y_1 w_1 + 55488\, x_1 w_1 + 70227\, w_1^2]\, w = 0 \qquad [2]
\end{aligned}
$$

Now by inspection it is evident that the equations [1] and [2] are identical (aside from the constant factor 3), if

$$(x_1, y_1, z_1, w_1) = (0, 0, 0, 1).$$

Hence one of the four points 0_1, 0_2, 0_3, 0_4 lies at the vertex D of the fundamental tetrahedron ABCD.

I shall next write down the equations of the nine lines *af*, *ag*, *ah*; *bf*, *bg*, *bh*; *cf*, *cg*, *ch*. The first three may be written as follows:

af: $x = 0, \quad w = 0$
ag: $y = 0, \quad w = 0$
ah: $z = 0, \quad w = 0$

The line *bf* may be written

$$bf: \quad \begin{cases} 3x + 4y + z = 0 \\ 32\,x + 27\,w \quad = 0, \end{cases}$$

since the equation of plane *b* takes the form

$$17\,(32\,x + 27\,w) - 96\,(3x + 4y + z) = 0.$$

The line *bg* may be written

$$bg: \quad \begin{cases} 8\,x + 6\,y - 3\,z = 0 \\ 64\,y - 51\,w \quad = 0, \end{cases}$$

since the equation of plane *b* takes the form

$$32\,(8\,x + 6\,y - 3\,z) - 9\,(64\,y - 51\,w) = 0.$$

The line *bh* may be written

$$bh: \quad \begin{cases} 2\,x - 3\,y + 6\,z = 0 \\ 32\,z - 17\,w \quad = 0, \end{cases}$$

since the equation of plane *b* takes the form

$$128\,(2\,x - 3\,y + 6\,z) - 27\,(32\,z - 17\,w) = 0.$$

In like manner, since the plane c may be written in any one of the forms

$$\begin{aligned} 17\,(32\,x + 27\,w) - 64\,(4\,x + 3\,y + 12\,z) &= 0, \\ 32\,(3\,x + 4\,y - 8\,z) - 3\,(64\,y - 51\,w) &= 0, \\ 32\,(3\,x - 2\,y + z) - 9\,(32\,z - 17\,w) &= 0, \end{aligned}$$

the equations of lines *cf*, *cg*, and *ch* are as follows:

$$cf: \quad \begin{cases} 4\,x + 3\,y + 12\,z = 0 \\ 32\,x + 27\,w \qquad = 0 \end{cases}$$

$$cg: \quad \begin{cases} 3\,x + 4\,y - 8\,z = 0 \\ 64\,y - 21\,w \qquad = 0 \end{cases}$$

$$ch: \quad \begin{cases} 3\,x - 2\,y + z = 0 \\ 32\,z - 17\,w \qquad = 0. \end{cases}$$

We have now to determine the equations of the lines 1, 2, 3, 4, 5, 6, each one of which passes through the point (0, 0, 0, 1) and is conditioned as stated in § 1. Considering line 1, its equations must be of the form

$$\begin{aligned} x + \lambda\,y + \mu\,z &= 0 \\ x + \lambda_1\,y + \mu_1\,z &= 0 \end{aligned}$$

and since it meets line *af*, we have the condition

$$\begin{vmatrix} 1, & 0, & 0, & 0 \\ 0, & 0, & 0, & 1 \\ 1, & \lambda, & \mu, & 0 \\ 1, & \square\,\lambda_1, & \mu_1, & 0 \end{vmatrix} = 0$$

giving $\lambda : \lambda_1 = \mu : \mu_1$ and hence line 1 may be written

$$x = 0, \quad \lambda\,y + \mu\,z = 0$$

Since it also meets line *bg*, we have the condition

$$\begin{vmatrix} 1, & 0, & 0, & 0 \\ 0, & \lambda, & \mu, & 0 \\ 8, & 6, & -3, & 0 \\ 0, & 64, & 0, & -51 \end{vmatrix} = 0$$

giving $\lambda = -2\mu$, whence the equations of line 1 are

$$1: \qquad x = 0, \quad 2\,y - z = 0$$

That this meets the line *ch* is obvious by inspection. Determining, in similar fashion, the equations of the remaining five lines, we obtain

$$\begin{array}{lrr}
2: & y = 0, & x + 3z = 0; \\
3: & x = 0, & 3x + 4y = 0; \\
4: & x = 0, & y - 2z = 0; \\
5: & y = 0, & 3x + z = 0; \\
6: & z = 0, & 4x + 3y = 0.
\end{array}$$

It is worthy of remark that the six lines 1, 2, 3, 4, 5, 6 lie on the quadric cone, of vertex D, whose equation is

$$12\,(x^2 + y^2 + z^2) - 5\,(6\,yz - 8\,zx - 5\,xy) = 0,$$

since the intersections of this cone by the planes $x = 0$, $y = 0$, $z = 0$ respectively, have for their equations

$$\begin{array}{ll}
x = 0, & (y - 2z)(2y - z) = 0; \\
y = 0, & (x + 3z)(3x + z) = 0; \\
z = 0, & (3x + 4y)(4x + 3y) = 0.
\end{array}$$

§ 3. It is apparent that, since the lines *af*, *ag*, *ah* all lie in the plane ABC ($w = 0$), the most convenient location for the plane of projection is the plane of the face ABC of the fundamental tetrahedron.

I next calculated the co-ordinates of the points where the six lines *bf*, *bg*, *bh*, *cf*, *cg*, *ch* meet two faces of the tetrahedron ABCD. In the case of the lines *af*, *ag*, *ah* no calculation has to be made, while for each one of the lines 1, 2, 3, 4, 5, 6, the co-ordinates of only one point have to be calculated. These results are given below in tabular form:

	x	y	z	w	
bf meets BC	0	—1	4	0	$y = -33\ 3$, $z = 133.3$
“ ACD	—27	0	81	32	$x = -27\ 2$, $z = 81\text{-}6$, $w = 32.2$
bg meets AC	3	0	8	0	$x = 27.2$, $z = 72\ 8$
“ BCD	0	51	102	64	$y = 20.3$, $z = 40.6$, $w = 25.6$
bh meets AB	3	2	0	0	$x = 60$, $y = 40$
“ BCD	0	34	17	32	$y = 35.5$, $z = 17.7$, $w = 33.4$
cf meets BC	0	4	—1	0	$y = 133.3$, $z = -33.3$
“ ABD	—27	36	0	32	$x = -57$, $y = 76$, $w = 67.6$
cg meets AC	8	0	3	0	$x = 72.8$, $z = 27.2$
“ BCD	0	102	51	128	$y = 31.4$, $z = 15.7$, $w = 39\ 5$
ch meets AB	2	3	0	0	$x = 40$, $y = 60$
“ BCD	0	17	34	64	$y = 12.8$, $z = 25.6$, $w = 48.2$
1 meets BC	0	1	2	0	$y = 33\ 3$, $z = 66.7$
2 “ AC	3	0	—1	0	$x = 150$, $z = -50$
3 “ AB	4	—3	0	0	$x = 400$, $y = -300$
4 “ BC	0	2	1	0	$y = 66.7$, $z = 33.3$
5 “ AC	—1	0	3	0	$x = -50$, $z = 150$
6 “ AB	—3	4	0	0	$x = -300$, $y = 400$

The right hand column of co-ordinates was made out for convenience in the construction, the edge of the tetrahedron ABCD (supposed regular) being taken equal to 100 units. Whenever a point lies on an edge of the tetrahedron, the sum of its co-ordinates is equal to 100, and when it lies in one of the faces of the tetrahedron, the sum of its co-ordinates is equal to 86.6, the altitude of the equilateral triangle forming the face.

The argument leading to the conclusion that the projection of the two triads of planes a, b, c; f, g, h from the point D upon the plane ABC ($w = 0$) gives the Pascalian configuration proceeds as follows. Consider the six planes a, b, c, f, g, h and the point of projection D, and the plane of projection ABC—then the line of intersection ab of the planes a and b

will be projected into a line *ab*, and the point of intersection of the planes *a*, *b*, *c* into a point *abc;* and so in the other cases (recalling the fact that the lines *af*, *ag*, *ah* already lie in the plane of projection as chosen). We have thus a plane figure, consisting of the fifteen lines *ab*, *ac*, ... *gh*, and of the twenty points *abc*, *abf*, ... *fgh*; and which is such, that on each of the lines there lie four of the points, and through each of the points there pass three of the lines, viz. the points *abc*, *abf*, *abg*, *abh* lie on the line *ab*; and the lines *bc*, *ca*, *ab* meet in the point *abc*, and so in the other cases.

Moreover, from an inspection of the scheme in § 1, we see that the projections of the lines *af*, *bg*, *ch* meet in a point, and the like for each of the six triads of lines; that is, in the plane figure, we have six points 1, 2, 3, 4, 5, 6, each of them the intersection of three lines as shown in the diagram

$$\begin{aligned}
1 &\equiv af \times bg \times ch \\
2 &\equiv ag \times bh \times cf \\
3 &\equiv ah \times bf \times cg \\
4 &\equiv af \times bh \times cg \\
5 &\equiv ag \times bf \times ch \\
6 &\equiv ah \times bg \times cf
\end{aligned}$$

and these six points lie in a conic (the intersection of the quadric cone by the plane of projection). It is clear that the lines *af*, *ag*. *ah*; *bf*, *bg*, *bh*; *cf*, *cg*, *ch* are the lines 14, 25, 36; 35, 16, 24; 26, 34, 15 respectively.

Conversely, starting from the points 1, 2, 3, 4, 5, 6 on a conic, and denoting the lines 14, 25, 36; 35, 16, 24; 26, 34, 15 (being, it may be noticed, the sides and diagonals of the hexagon 162435) in the manner just referred to, then it is possible to complete the figure of the fifteen lines *ab*, *ac*, ... *gh* and of the twenty points *abc*, *abf*, ... *fgh*, such that each line contains upon it four points, and that through each point there pass three lines, in the manner already mentioned.

Of the fifteen lines, nine, viz. the lines *af*, *ag*, *ah*; *bf*, *bg*, *bh*; *cf*, *cg*, *ch* are, as has been seen, lines through two of the six points 1, 2, 3, 4, 5, 6; the remaining lines are *bc*, *ca*, *ab*; *gh*, *hf*, *fg*, These are Pascalian lines

bc of the hexagon 162435,
ca " " 152634,
ab " " 142536,
gh " " 152436,
hf " " 142635,
fg " " 162534,

which appears thus, viz.

$$\begin{aligned} \text{line } bc \text{ contains points } & bcf,\ bcg,\ bch, \\ & = bf\,.\,cf,\ \ bg\,.\,cg,\ \ bh\,.\,ch \\ & = 35\,.\,26,\ \ 16\,.\,34,\ \ 24\,.\,15; \end{aligned}$$

that is, *bc* is the Pascalian line of the hexagon 162435; and the like for the rest of the six lines.

The final conclusion has already been stated above in § 1. The drawing explains everything; a few words of explanation and interpretation, however, are perhaps not amiss. By means of four separate scales and the employment of a number of principles of Graphics, I first laid down the tetrahedron ABCD and the fifteen lines in space, *af*, *ag*, *ah*; *bf*, *bg*, *bh*, *cf*, *cg*, *ch*; and 1, 2, 3, 4, 5, 6. In the drawing, the projection of the line *af* is written (*af*), and so in other cases. The projection of the line *bf*, for example, was found by joining the meets of the lines 5 and *bf* with the plane of projection, and similarly for other cases. Only three of the Pascalian lines, viz. *bc*, *ca*, *ab* were drawn, to avoid giving the figure a too complex appearance. The projection of line *ab*, for example, was obtained in the following manner: lines *ag*, *bg* lying in planes *a* and *b* respectively intersect in a point P, say, on the line *ab*; the projections of the points P and P_1 are the meets of the projections of the pairs of lines *ag*, *bg*; *ah*, *bh* respectively. The projection of line *ab* then is the join of the projections of the points P and P_1.

The Steiner point S (shown in the figure), the common meet of the three Pascalian lines *bc*, *ca*, *ab*, is one of the *two*

Steiener points yielded by the projection, the other not being shown for the reason mentioned above.

A final consideration was the construction of the conic section, given by the intersection of the quadric cone (containing the lines 1, 2, 3, 4, 5, 6) with the plane of projection. The six points 1, 2, 3, 4, 5, 6 lie on this conic section and hence it was constructed by points by means of the very theorem under consideration, viz. Pascal's Theorem.*

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* To prevent unnecessary complexity on the drawing, only one branch of the hyperbola (the conic, in the present instance) is shown.

WORKING UP THE ENTOMOLOGICAL FAUNA OF NORTH CAROLINA.

FRANKLIN SHERMAN, JR., AND C. S. BRIMLEY.

The authors having joined in an effort to work up as completely as possible the insect life of the State, it is deemed advisable to present a brief account of the work thus far accomplished.

Owing to the vast number of species, the extreme difficulty of classification, and the average comparative small size of the subjects, the task of working up the entire entomological fauna of a State is an unending one—we can only hope to make a start, lay the foundations, and erect as much of the final structure as possible. We can never hope to complete the undertaking. By devoting ourselves more or less closely to certain groups we have been able to get the list of species within those groups fairly well represented in our collections and records. When a species is determined positively to occur within the State the name is written on a card and placed in our permanent files, together with a brief note as to the locality or localities where it is known to occur. To keep this record complete, therefore, we must not only record our own captures but must keep a close watch on the literature and record all authentic observations of others who may at one time or another make collections within our limits.

During 1903 we gave special attention to the Odonata (Dragon-flies) and the Rhopalocera (Butter-flies). Of the Odonata twenty-two species were added to the sixty already known to occur in the State, the most noteworthy addition being probably *Telagrion daecki*, Calvert, only described for the first time in February, 1903, and which was found by Mr. Brimley to be locally abundant near Raleigh in June. The total number of species of the butterflies was raised to one hundred and three, (this does not include, of course, the night-flying moths), the most interesting additions being *Melitea phaeton*, Drury, bred from larvae taken at Tryon, Polk county, by Mr. W. F. Fiske; *Pamphila carolina, Skinner*, taken commonly at Raleigh from March 24th to April 18th by Brimley and Sherman; *Calephelis caenius*, Linn, taken at Fayetteville, July 10th, by Mr. S. W. Foster; *Apatura celtis*, Boisduval and Leconte, taken at Smithfield by Mr. Foster; and three not yet identified Hesperids taken by Mr. Sherman at Washington, Beaufort county, and Beaufort, in Carteret county.

Some work was also done on the first three families of moths, the Sphingidae, Saturniidae and Ceratocampidae, the last two families, which include nearly all of our largest species of moths, being now represented on our records by nearly all the species likely to occur in the State. A list of all the species of these three families now known to occur in North Carolina was published in *Entomological News* for April, 1904, by Mr. Brimley.

In the order Diptera the most exhaustive work was done on the Tabanidae (Horse-flies), forty identified species and one not yet located having been so far secured. The species of this family were identified by Prof. J. S. Hine, of Columbus, Ohio, who has described as new two of the species collected by Mr. Brimley, one of which he has named *Chrysops Brimleyi* in honor of the discoverer. The family Asilidae (Robber-flies) has been explored to some extent, thirty-two species being now known to occur in the State. One of these, *Dasyllus cinerea*, Back, was described as new from specimens taken at Southern Pines in late March, 1903.

In the Coleoptera (Beetles) the list of Cicindelidae (Tiger-beetles) seems about complete. A list of these, comprising nineteen species, was published in *Entomological News* for January, 1904. The Meloidae (Blister-beetles) are now represented in our collections and records by eleven identified and two not yet identified species, which probably include about all that occur in the State. This order, the Coleoptera, has been more thoroughly explored in a general way than any other of the large orders. In all, one thousand and eight species of Coleoptera are now recorded in our lists from the State.

The order Hemiptera (True Bugs, Scale-insects and Plant-lice) has been gone over in a preliminary way, but not in detail as yet. In this order, the family Coccidae or Scale-insects, which includes such important economic forms as the Scurfy Scale, the Oyster-shell Scale and the San Jose Scale, is now known to be represented by not less than thirty-two species.

Among the Neuropteroid insects (excluding Odonata already mentioned) some work has been done and a few quite rare forms have come to light, among these being *Panorpa rufa*, Gray, previously known by only one specimen from Georgia in an English Museum from which the species had been described. Our specimen was taken at Wilmington on Christmas day, 1902.

The entire list of true insects thus far known to occur in North Carolina as shown by our records includes one thousand seven hundred and ninety-seven species. A number of other species have been collected but not yet identified.

As an incentive to others who may feel an interest in work of this kind it may be stated that there yet remain whole groups of insects in which little or nothing has been done, and many unknown and interesting secrets await the investigation of the patient, industrious, persistent collector.

A CASE OF SNAKE-BITE.

BY THE VICTIM, C. S. BRIMLEY.

On January 21, 1901, I was bitten by a small Cottonmouth (*Ancistrodon piscivorus*) about 260 mm, or 10 2-5 inches long. It happened thus: I had received a number of small snakes tied up in bags to keep them separate, in the pail they were sent in, and there was nothing in the accompanying letter to lead me to think a Cottonmouth was among them (the shipper knew the species). After I had taken this snake out of the bag and seen what it was, I dropped him back again and took hold of it in order to tie it up, when the snake immediately struck at me and drove one fang into the fourth finger of my left hand, on the under side of the last joint.

I sucked the wound well and then ligatured it below the puncture, and immediately went to my doctor (A. O. Jones), taking about one-half an hour to get there. He cupped the wound with a bottle half full of ammonia, getting a good deal of blood, and then injected potassium permanganate into the finger just below the wound which caused it to pain me exceedingly, flooded whole finger with the solution and removed the ligature. I then returned home.

The pain was a sharp smart till about half way to the doctor's, when it nearly ceased. After getting back home finger began to swell and a burning ache set in in wound, which though not very violent kept me awake some time after I had retired. I got to sleep about 12, woke up at 4 A. M. and swelling had spread considerably over back of hand but finger hurt less; a slight feeling of soreness showed itself in my arm both above and below the elbow and in the morning there was a slight soreness at the shoulder. Permanganate bandage was kept on finger till 4 A. M. January 22 and was soaked twice with the solution (after coming home and before going to bed). Took no alcoholic or other stimulant. Thumb, middle finger and index finger and part of hand and wrist adjacent were not affected. Under side of hand did not swell. My system was not affected at all, except the local trouble in hand and arm.

Swelling on back of hand was all gone by morning of January 24, and by January 26 the swelling and inflammation was mostly confined to the neighborhood of the bite, but there was still some stiffness in the finger and back of hand was still somewhat tender.

The place where the permanganate was injected festered and I pressed pus out of it on January 26. By January 28 my hand was practically well and entirely so by February 1.

FURTHER NOTES ON THE REPRODUCTION OF REPTILES.

BY C. S. BRIMLEY.

On July 18, 1903, five eggs were brought to me, which proved to be those of *Eumeces fasciatus* (Blue-tailed Lizard), these were about the size of Cnemidophorus eggs, measuring 20x12, 20x15, 22x11, the fifth, from which a full grown embryo, ready to hatch and showing the usual markings of the species, had been removed, was not measured. The eggs were very smooth and the skin was very thin, almost transparent, and of a dirty white in color; shape varying from a rather short to a rather long oblong, one of the eggs was one-sided; they were said to have been found near Swift Creek, in this county.

On July 28, 1903, three eggs measuring 30 to 31 mm. long were received. These were long and slender, and were attached to one another on the side, so that their long axes were parallel, one, which was opened, contained a snake embryo too small to identify, and I was not successful in my attempt to hatch them. The probability is that they were the eggs of the Red King Snake (*Ophibolus coccineus.*)

In August, 1903, some *Kinosternon flavescens* in my possession from Austin, Texas, laid two eggs. These were hard-shelled like those of other Mud Turtles, and measured 25x16 and 26x16.

In my former paper read before the Academy in November, 1902, I omitted any mention of *Terrapene carolina* and *T. bauri*, although both species have been hatched out in my "Terrapin pen" from eggs laid in confinement. I have never seen the female in the act of covering her eggs but once, and then she was pressing down the earth as hard as she could. The young of these turtles hatch out in October, unlike those of our water-turtles, which mainly remain in the shell till the next spring. The eggs which I have dug up in October with young in them ready to hatch are about the size and shape of the eggs of Deirochelys and like them are soft shelled.

I had the pleasure of examining last spring the eggs of the Painted Turtle (*Chrysemys picta*) in situ. The "nest" was situated on a sloping hill-side a little above the reach of the inundations of Walnut Creek, and consisted of a hole in the hard ground in which three eggs had been laid, and the entrance had then been filled with earth and this pressed down hard by the animal's feet. The earth was not in contact with the eggs, which were loose in the cavity below. Externally the nest looked as if some one had thrown a little "pat" of wet clay on the ground and it had dried there. The dirt was so hard it was quite difficult to dig through it to the eggs.

The eggs of Kinosternon on the other hand have the earth packed down hard on them and the entrance to the nest is closed so as to leave a slight depression.

With regard to Lizard eggs Sceloporus lays its eggs in lots of 10 or thereabouts, while the Sand Lizard only lays three at one time.

SOME INTERESTING INSECT CAPTURES.

BY FRANKLIN SHERMAN, JR.

Under this title we wish to record the occurrence in North Carolina of a few of the interesting species of insects which we find from time to time as we are able to study the fauna of the State, and our own collections, more closely.

From the tops of such mountains as Mitchell and Grandfather, to the low swamps of Brunswick county, our State supports a fauna which in richness is equalled by few. One must actually traverse the ground, and study the forms of life in the different regions, to fully realize how great this variation is.

Papilio cresphontes, Cramer, (The Orange Dog). This butterfly, which is doubtless the largest that occurs within our borders, is typically a southern species and is common in Florida, where the caterpillar feeds on the leaves of the orange, thus earning the popular name of The Orange Dog. But in later years the species seems to have been gradually spreading northward and in 1898 the author took one specimen in Maryland, eight miles from Washington. In 1900 three specimens were taken at Ithaca, N. Y., and we have been informed that several others, as well as caterpillars of the species, have since been taken there. It has also recently been taken in Ontario, and Mr. W. J. Holland records it as rather common about Pittsburg. My friend, Mr. C. S. Brimley, who has for years been a thorough student and collector of butterflies in the vicinity of Raleigh, has been unable to locate this species. On August 9th, 1902, one specimen was taken on Shackleford Banks, near Beaufort, Carteret county. It seems likely that in its northern migrations it has remained near the coast, and when the cooler regions are reached, it probably follows the warmer valleys along the watercourses from which specimens may wander inland. It would still seem strange, however, that the species should remain unknown at Raleigh.

Papilio palamedes, Drury, (Palamedes). This species is even more southern in its distribution than *cresphontes*, and is recorded to occur "from southern Virginia, near the coast, to the extreme southern end of Florida, and westward to southern Missouri and Texas." Like the preceeding, it is not known at Raleigh, and in all probability never occurs there, but two specimens were taken at Beaufort on August 11th, 1902, and at least one or two others were observed at that time.

Thecla damon, Cramer, (The Olive Hairstreak). While this species is probably native to all parts of the State, it is not likely that it is ever abundant, and but one specimen has fallen to me in two years. Mr. Brimley, however, has two or three records of its occurrence at Raleigh. Our one specimen was taken at Durham, on R. F. D. Route No. 2, about 10 miles from town. The little butterfly is exceedingly active, darting quickly in a zig-zag flight which we found it almost impossible to follow with the eye. A peculiar feature which pertains to most of the species of this genus is the very plain unmarked upper surface of the wings, and the usually conspicuously marked under surface. The species can scarcely be distinguished at all by examining the upper surface, but a mere glance at the lower surface decides the matter quickly.

Thecla M-album, Boisduval & Leconte, (The White M-Hairstreak). This pretty little species is said by Holland to have been "taken as far north as New Jersey and Wisconsin, and ranges southward to Venezuela" and that "its citadel is found in the live-oak hummucks of the Gulf States and the oak forests on the highlands of Mexico and more northern countries." This would seem to indicate that in general, the species is too southern in its range to be at all common in North Carolina. Our only specimen, (which is somewhat mutilated), was taken at Blowing Rock on August 29th, 1902. Mr. Brimley does not find the species at Raleigh. Like the preceding species it seems to be very active in flight.

Thecla halesus, Cramer, (The Great Purple Hairstreak.) This, which we regard as one of the most handsome of all our species, is said by Holland to be "Very common in Central America and Mexico; it is not scarce in the hot parts of the Gulf States, and is even reported as having been captured in southern Illinois. It also occurs in Arizona and southern California." While it is thus assigned as typically a subtropical species, we found it not at all rare at Lumberton on September 6th, 1902. Three specimens, representing both sexes, were captured, and one or two others were observed. This is one of the largest species of the genus, and, unlike the others here discussed, it is rather easily taken. One of my specimens was swung at with the net not less than four times, yet made no long flights. It may be that it was only common in the one locality and for a short time, but it seemed to be quite at home. We regard this as a significant capture, indicating that many sub-tropical forms may hereafter be taken in our southeastern section. It is not on record from Raleigh.

Phyciodes nycteis, Doubleday & Hewitson, (Nycteis). The Nycteis butterfly is recorded "from Maine to North Carolina and thence westward to the foothills of the Rockies," and seems to be found only in the western part of our State. Mr. Brimley does not list it from Raleigh, and our one specimen is from Blowing Rock, where it was taken in June, 1901. A somewhat similar species, (*Phyciodes tharos*), is common in all parts of the State.

Grapta faunus, Edwards, (The Faun). Holland says that *faunus* is "found from New England to the Carolinas, thence westward to the Pacific." It is not recorded from Raleigh, and seems to be very local in distribution and only found in the higher colder localities. On August 30th, 1902, it was found not uncommon along the turnpike road from Blowing Rock to Linville. It was my good fortune to be accompanied on that trip by a collector who had had considerable experience in the Adirondacks, and who stated that it was a common species there. It is not on record from Ithaca, New York, though that region has been very thoroughly collected in.

Pomphopoea unguicularis, Leconte. Our present subject is the largest of the Blister beetles (Meloidae) which we have yet taken in the State. Mr. Schwartz, of the U. S. National Museum, who is probably the best authority on beetles in the country, tells me that it "is sometimes locally common in the mountains." Surely it was plentiful at Blowing Rock on June 26th, 1901. They were feeding on the leaves and fading flowers of the mountain laurel in great numbers. Their scratching among the thick leaves and twigs of the bushes was plainly audible at a distance of a rod or more. Several hundred were taken, and as many more might have been had if desired. Only a few bushes were found to be infested by them, others only a few hundred feet away being unmolested. One party informed us that they had attacked the roses to such an extent that it became necessary to spray them. We also found them abundant on certain peach trees, where they fed on the foliage, and noted the curious fact that they showed a decided preference for leaves that had already been deformed by the Leaf Curl. As many as eight or more were found on a single curled leaf. This fact is also of interest as showing one of the many means by which plant diseases may be dispersed.

MOLECULAR ATTRACTION.*

(THIRD PAPER)

BY J. E. MILLS.

In a preceding paper[1], making use of the measurements of Profs. Ramsay and Young and of Prof. Young, we applied the theoretically derived equation,

$$\frac{L - E_1}{\sqrt[3]{d} - \sqrt[3]{D}} = \text{constant}, \tag{1}$$

to twenty-one substances, and called particular attention to variations in the constants obtained and to the range of temperature covered by the measurements. (In the above equation, L denotes heat of vaporization, E_1 is energy spent in overcoming external pressure, and d and D denote density of liquid and vapor respectively.) In this paper making use of the same measurements and the results there derived we wish to point out some further applications of the theory. But first we call attention to several points bearing more directly upon the results of the last paper.

The constant given by equation 1 above, as will appear later in this article, is an important property of a substance, and depends upon the attraction of one molecule for another. We have to refer to this constant so often that a more specific designation is desirable. We have hitherto called the absolute attraction at unit distance from a molecule μ. The above constant we will call μ'. (Therefore $\mu = c_4\mu'\sqrt[3]{m}$). We call the internal latent heat of vaporization λ and therefore have,

$$\lambda = \mu' (\sqrt[3]{d} - \sqrt[3]{D}). \tag{2}$$

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* Reprinted from the Journal of Physical Chemistry, Vol. 8, No. 9, Dec. p. 593 (1904).

[1] Jour. Phys. Chem., June, 1904. Referred to in this article as "second paper."

THE $\frac{\delta P}{\delta T}$ AT THE CRITICAL TEMPERATURE.

In the second paper we commented upon the difficulty of obtaining correctly the $\frac{\delta P}{\delta T}$ from Biot's formula near the critical temperature. We entirely overlooked the fact that the constant b of the equation, $p = bT - a$, proposed by Profs. Ramsay and Young, was also a $\frac{\delta P}{\delta T}$ and that at the critical temperature (but only at that point, see p. 166) the $\frac{\delta P}{\delta T}$ of the two equations became identical. In work done to establish the truth of the equation, $p = bT - a$, the $\frac{\delta P}{\delta T}$ was obtained for three substances at volumes practically identical with the critical volume. The results are such as to confirm entirely and quantitively the view that the divergences at this point in μ were due to the Biot formula used to obtain the $\frac{\delta P}{\delta T}$.

Thus isopentane gives at the critical temperature (volume 4.266) the $\frac{\delta P}{\delta T} = 367.8$, calculated from Biot's formula. Prof. Young[1] found from drawn isochors (at the volume 4.3) the value 397, and a calculated value of 407. Therefore Biot's formula gives results about ten per cent. too low, an amount just sufficient to explain the variations in μ' near that point.

For normal pentane Biot's formula at the critical volume, 4.303, gives 364,8 for the $\frac{\delta P}{\delta T}$. Mr. J. Rose-Innes and Dr. Young[2] obtained 407.3 from drawn isochors. Biot's formula therefore shows results too low by about eleven per cent., an amount which is sufficient to explain the low values obtained

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[1] Proc. Phys. Soc., 1894-95, p. 650.

[2] Phil. Mag., April, 1899.

in the constant μ' as the critical temperature was approached.

For ethyl oxide Profs. Ramsay and Young[1] obtained at volume 4.00 the $\frac{\delta P}{\delta T} = 413.7$, and it is evident from their paper on ethyl oxide[2] that the values they used for calculating the latent heat of vaporization point to a value at this point of about 490, a fact which sufficiently explains the rise noted in the value of μ'. (The values Profs. Ramsay and Young used for $\frac{\delta P}{\delta T}$ at this point are not in accord with the Biot formula they publish and this prevents quantitive comparison here. See p. 175.)

We have therefore direct proof that the equation, $\frac{L - E_1}{\sqrt[3]{d} - \sqrt[3]{D}} =$ constant, is applicable in the immediate neighborhood of the critical temperature.

THE PRODUCT OF THE PRESSURE AND THE VAPOR DENSITY.

In examining the data used to discover if possible the immediate source of variations in μ' it proved impracticable to plot either the pressure or the volume of the vapor directly against the temperature. But their product, PV, varied more slowly and the values were plotted and gave regular curves except for di-isobutyl, brom-benzene, iodo-benzene, hexamethylene, and water. This result is so interesting that the curves are given below, Diagrams 1 to 3. The numerical results are given in Tables 1 to 21. For water the break in the regularity of the curve occurs at 100° C, and since different formulas were used for the vapor pressure above and below that temperature it would seem certain, in view of remarks already quoted (second paper, p. 396), that the formulas for the pressure need adjustment. For di-isobutyl,

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[1] **Phil. Mag., May, 1887.**

[2] **Phil. Trans., 1887A, p. 57.**

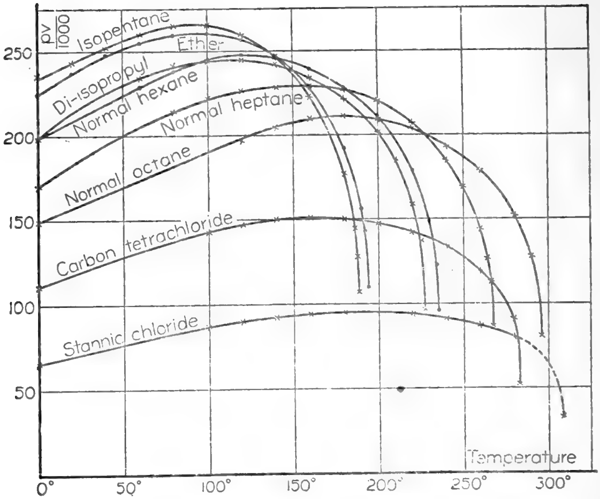

Diagram 1.

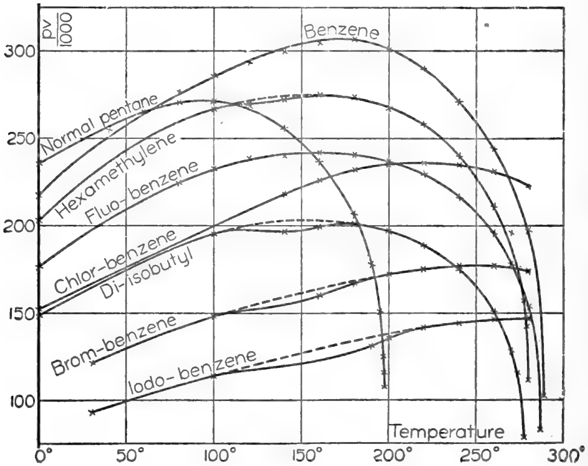

Diagram 2.

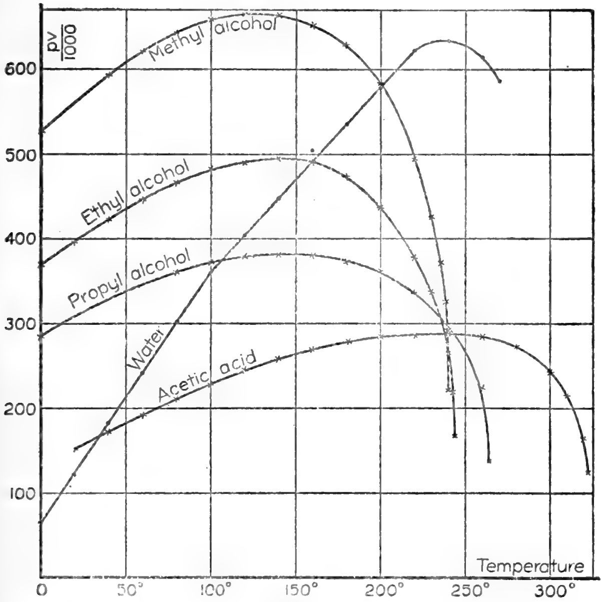

Diagram 3.

For water, add 900 to the ordinates shown by the diagram.

brom-benzene, iodo-benzene, and hexamethylene, the irregularities of the PV curve are more probably due to the vapor density (see second paper, p. 400), and are especially interesting because they occur at just the point where were obtained divergent values for μ'. Reference to the preceding paper will show that di-isobutyl, brom-benzene, and iodo-benzene, were the only substances, except stannic chloride and the associated substances, giving divergences (which have not been explained as due to multiplication of error in calculating the $\frac{\delta P}{\delta T}$) greater than two per cent. from the mean value adopted for μ'. Hexamethylene shows likewise a smaller though well marked divergence in μ' corresponding to the concave sink in the PV curve.

It is clear therefore that these abnormal values of the PV product must be carefully investigated before the corresponding divergences in μ' can be regarded as in any way evidence against the theory by which that constant is derived.

INTERNAL HEAT OF VAPORIZATION.

The internal heat of vaporization was plotted against the temperature, Diagrams 8 to 10. These curves are more fully discussed later (p. 161). We would here call attention only to one feature of these curves, viz.: Corresponding to divergences in μ' there appear irregularities in these curves and these variations would (excepting in stannic chloride and the associated substances) for the most part disappear if the curves were smoothed, and the smoothed values thus obtained used in the calculations.

DIAGRAM OF $L - E_i$ AGAINST THE $\sqrt[3]{d} - \sqrt[3]{D}$.

We have plotted, Diagrams 4 to 7, the results for all of the

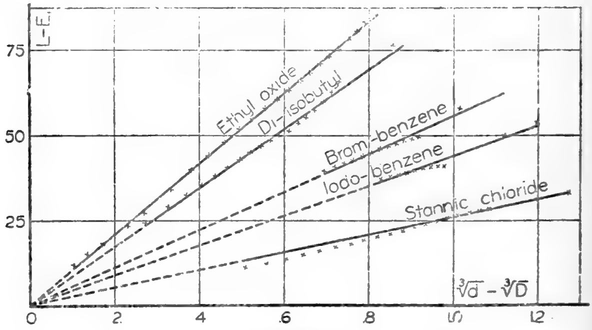

Diagram 4.

Ordinates give internal heat of vaporization in calories. Abscissæ give difference of the cube roots of the densities of liquid and vapor.

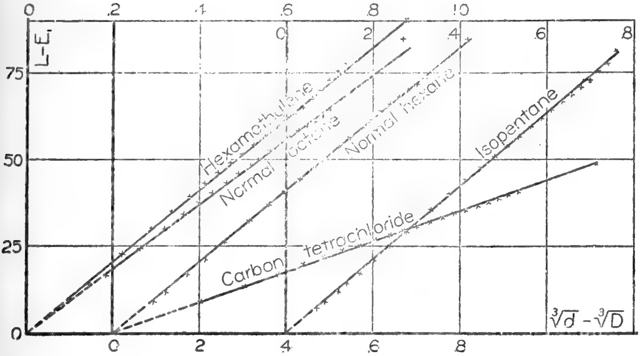

Diagram 5.

Ordinates give internal heat of vaporization in calories. Abscissæ give difference of the cube roots of the densities of liquid and vapor.

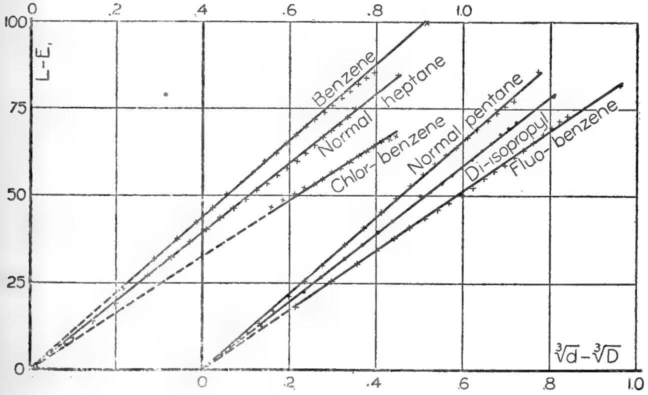

Diagram 6.

Ordinates give internal heat of vaporization in calories. Abscissæ give difference of the cube roots of the densities of liquid and vapor.

substances examined, using the values of $L - E_1$ for ordinates and the values of $\sqrt[3]{d} - \sqrt[3]{D}$ for abscissæ. This is desirable in order to give a more exact idea of the relative extent and importance of the observations. For since neither

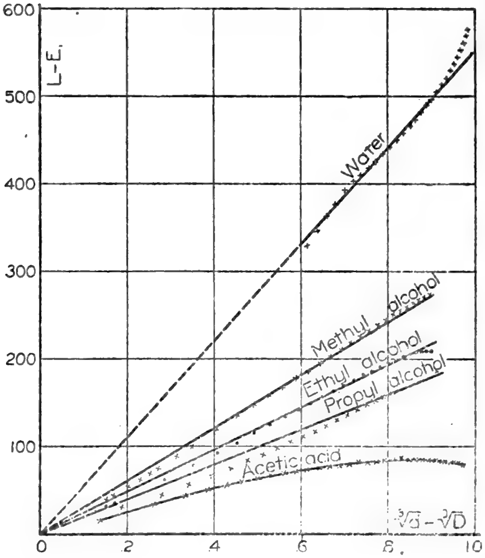

Diagram 7.

Ordinates give internal heat of vaporization in calories. Abscissæ give difference of the cube roots of the densities of liquid and vapor.

L — E, nor $\sqrt[3]{d} - \sqrt[3]{D}$ vary uniformly with the temperature observations taken every ten degrees are consequently not taken at equal intervals of the curve (a straight line) represented by that equation.

Through each set of observations, excepting for acetic acid, the mean line is drawn. The constants for this mean line were obtained by averaging, for any substance, all of the constants recorded in Table 1 (second paper) that were within two per cent. of the mean values adopted in that table. For di-isobutyl the mean value adopted appeared probably too high and we therefore choose the value 86.3 as being more nearly in accord with the proper constant. The values for these constants are given in Table 25 under the heading μ'.

For ethyl oxide, di-isopropyl, di-isobutyl, isopentane, normal pentane, normal hexane, normal heptane, normal octane, benzene, hexamethylene, fluo-benzene, carbon tetrachloride, methyl alcohol, ethyl alcohol, propyl alcohol, and acetic acid, sixteen substances in all, the observations are practically complete, extending from near the freezing point of the liquid nearly to the critical temperature. Among these sixteen substances the only divergences appearing marked to the eye are normal octane and ethyl alcohol at 0° C, di-isobutyl, those for the alcohols as the lines approach the origin, and acetic acid.

The curves for chlor-benzene, brom-benzene, iodo-benzene, stannic chloride, and water, are not complete. All of these incomplete curves show irregularities and yet it is made most evident by the diagrams, as well as by what has already been said, that with the exception of stannic chloride, the divergences are not so pronounced as to be considered weighty evidence against the theory.

In conclusion therefore we point out that, of the twenty-one substances examined, stannic chloride and the associated substances (methyl alcohol, ethyl alcohol, propyl alcohol, and acetic acid) are the only substances that show variation in μ' without at the same temperature exhibiting irregularities in the data used. That these irregularities in the data are due to the measurements is much to be doubted. But if not so produced they are significant of unknown changes taking place in the substance under examination—changes which were not taken into account in the theory of molecular attraction under discussion and to which that theory as outlined would not be strictly applicable.

THE LATENT HEAT OF VAPORIZATION.

It is interesting to examine more closely and to compare the heats of vaporization calculated by use of the following equations:

$$\text{[3]} \qquad L = \frac{T}{J}(V - v)\frac{\delta P}{\delta T}.$$

$$\text{[4]} \qquad L = \mu'(\sqrt[3]{d} - \sqrt[3]{D}) + E_1.$$

$$\text{[5]} \qquad L = 2\,RT \log_e \frac{d}{D}.$$

Using the constants we have hitherto adopted, the equations become:

$$\text{[6]} \qquad L = 0.0_431833\,T\,(V - v)\frac{\delta P}{\delta T}\text{ cals.}$$

$$\text{[7]} \qquad L = \mu'(\sqrt[3]{d} - \sqrt[3]{D}) + 0.0_431833\,P\,(V - v)\text{ cals.}$$

$$\text{[8]} \qquad L = \frac{9.1522}{m}\,T \log \frac{d}{D}\text{ cals.,}$$

m being the molecular weight, with oxygen equal to 16 as the standard, and logarithms to base ten.

The equations are all theoretically derived.

Equation 3 rests primarily upon the first and second laws of thermodynamics and is deduced therefrom by a familiar line of reasoning. No assumption is made as to the nature or cause of the latent heat, or as to the nature of the substance itself. The equation will serve as well to calculate the latent heat of fusion or the energy absorbed during the change in the crystalline form of a solid. It merely expresses the energy necessary to effect a change in volume under given conditions, and is silent as to the cause of the change or the nature of the substance. So far as present knowledge goes, there is no need for questioning the correctness of the results obtained by this equation, the data being accurate. We can therefore well use the latent heat so obtained as a check, either upon direct measurements of the latent heat, or upon other calculations involving relations and assumptions, which perhaps are true, but which are not so fundamental.

We have already published (second paper, Tables 2 to 22; the calculations for six or seven of the substances were, however, the work of others) the results obtained by the application of this equation to twenty-one substances, and only for the sake of comparison repeat a portion of the results in the tables which follow. (See Tables 1 to 21, under the heading Ther.) It must be borne in mind that although these results are accurate where the data is correct, yet errors in the measurements may, and oftentimes certainly do, (because of the method necessarily followed for obtaining the $\frac{\delta P}{\delta T}$) produce far greater proportional errors in the result.

Equation 4 is derived by a simple transposition from equation 2 of the second paper. The assumptions upon which that equation is founded and evidence bearing upon the equation, have been discussed in the preceding paper and here we would only summarize by saying that this equation rests upon the belief that the total kinetic energy of a molecule of a liquid and of its vapor, at the same temperature, are the same; and upon the further assumption that the entire latent heat of vaporization is expended in overcoming the external pressure and in separating the molecules against the action of an attractive force varying inversely as the square of the distance apart of the molecules. The equation is not applicable (*a priori*) if (*a*) the number of molecules change owing to dissociation or decomposition; or if (*b*) the molecules are not evenly distributed throughout the space occupied by them; or if (*c*) for any reason the attraction between these molecules varied with the temperature.

The constant μ' for the twenty-one substances examined are given in Table 25 of this article under the heading μ' and while the constants there given were obtained by a comparison of this equation with the thermodynamical results obtained by use of equation 3, it is easily seen that such a method of obtaining the constant is, we might say, incidental, and was only adopted for the sake of accuracy and convenience. One accurate measurement at *any* temperature of the latent heat of vaporization of any substance to which the equation is applicable, together with a measurement of its vapor pressure and of the densities of liquid and vapor, would enable the constant for that substance to be calculated. The equation has, therefore, no connection with the thermodynamical equation 3, but rests independently, partly upon the same and partly upon additional assumptions.

The results obtained for the twenty-one substances are given later, Tables 1 to 21, in the columns marked Mills.

In comparing the latent heats so calculated with those obtained from the thermodynamical equation we find that if the five associated subtances be omitted, there are only four determinations in which the results as calculated by the two equations differ by so much as two calories, viz.: di-isobutyl at 0°, normal octane at 0°, chlor-benzene at 270°, and brom-benzene at 30°—in every instance the divergences being at the end point of the Biot curve and thus making it probable that all of these divergences are due to the thermodynamical equation. Excepting stannic chloride, there are only twelve other substances in which the divergence is greater than one calorie. All of these divergences are marked with an asterisk in the tables. This comparison emphasizes more clearly than is possible in any other way the correctness of the law of molecular attraction we have assumed.

Accurate calorimetric measurements are exceedingly difficult even under ordinary pressures and it is not too much to say that where equation 4 is applicable, latent heats calculated with its aid will be more accurate than direct measurements of that quantity, unless very great care is taken in the measurements.

Equations 3 and 4 give with the associated substances and with stannic chloride an agreement which is partial but not complete, divergences being shown at the higher temperatures. One or more of the modifying causes mentioned on page 155 may here be operative.

Equation 5 was deduced by Mr. H. Crompton. Mr. Crompton considers the change in density as if it were due to pressure alone, then in order to keep the substance at that density without the excess of pressure doubles the amount of energy required. Thus he has,

$$[9] \qquad L = 2\int_v^V p\delta v = 2\,RT \log_e \frac{d}{D}.$$

Mr. Crompton makes no supposition as to the true cause of the change of density. But he proceeds on the principle that in effecting a given change of condition the process pursued is immaterial if the total energy change is alone to be considered, the idea being that the change in density could, theoretically, have been produced by pressure. The law governing the change of pressure with the density is known, therefore the amount of energy involved in the change of state can be calculated.

Mr. Crompton uses as the law governing the change of pressure with the volume, the gas equation, $PV = RT$. But since Mr. Crompton deals with an ideal condition, from which the action of forces other than the pressure are by assumption removed, his equation is not limited to those temperatures for which that equation holds true. It is necessary, however, that $PV = RT$ should represent the true law of pressure for the substance, which is ideally considered only in a limited sense. (The material size of the molecules or some effect of the temperature, etc., *might*, therefore, affect the exactness of the law.) It will be further recognized that Mr. Crompton's equation, no less than equation 4 above, involves the assumption that the only energy change is that involved in a change in density—that is a change of potential energy,—and the total kinetic energy of the molecules of the liquid and of the gas must be the same. As a consequence it is to be expected, though not with certainty owing to possible compensation, that the theory would not apply to substances more associated in the liquid than in the gaseous condition. In the tables below, 1 to 21, in the column headed "Crompton" we give the results obtained from this equation for the substances under examination. For additional evidence bearing upon the theory see Jour. Phys. Chem., April, 1902, p. 219 and Proc. Chem. Soc., Vol. 17, 233, 1901.

It appears that *at low temperatures, where the vapor pressure is small, the results are invariably, and usually very considerably, too large. But at the highest temperatures examined for each substance the agreement is good,* the divergence at this temperature being greater than one calorie only in the cases of ether, normal octane, stannic chloride, and four of the five associated substances.

The results therefore merit detailed study, Of the twenty-one substances, twelve, viz.: ether, di-isopropyl, isopentane, normal pentane, normal hexane, benzene, hexamethylene, fluo-benzene, chlor-benzene, brom-benzene, iodo-benzene, and carbon tetrachloride, give results that are in all respects similar. With them at the lower temperatures Crompton's theory gives too high results, but as the temperature is raised the results grow in the main continually closer to those given by the thermodynamical equation. For these substances after a vapor pressure of 7000 mms. has been reached, it may be said that Crompton's theory gives a very fair approximation, usually within one calorie, to the results obtained thermodynamically.

Di-isobutyl, normal heptane, and normal octane, each show a good agreement at the lowest temperature for which the vapor pressure was measured, viz.; 100°, 80°, and 120°. Then with increasing temperature Crompton's equation gives results lower than those obtained thermodynamically.

Stannic chloride is similar to the above in showing better agreement at the lower temperatures than at the higher, but in this case Crompton's results are uniformly the larger.

In the case of water the results of Crompton are always the larger, but had the observations been continued nearer the critical temperature it is quite possible that good agreement would have been reached.

With the three alcohols, Crompton's equation gives entirely too high results at the lower temperatures. Then with rise in temperature the results from Crompton's equation become decidedly the lower, but near the critical temperature the difference is not very marked.

With acetic acid, Crompton's equation gives results more than twice too large at the lowest temperature. As the temperature is raised the disagreement becomes continually less. It must be borne in mind that acetic acid vapor shows marked association.

Comparing the three equations, the value of Crompton's theory becomes doubly apparent. Crompton's equation does not involve the vapor pressure and therefore, if trustworthy, will act as a check upon the thermodynamical equation at the end points of the curve, where, owing to the manner of obtaining the $\frac{\delta P}{\delta T}$, the thermodynamical results are somewhat uncertain. On the other hand compared with equation 4, Crompton's theory does not depend upon the attraction and would not be affected by a variation of the attraction with the temperature. It should therefore furnish a clue to those substances in which the molecular attraction does not remain constant with increasing temperature.

At low temperatures Crompton's equation gives values uniformly too high and it therefore cannot be used to check the results of the other equations. But at the highest temperatures the evidence obtained from the results is exceedingly interesting. For ether, di-isoproprыl, isopentane, normal pentane, normal hexane, benzene, hexamethylene, fluo-benzene, and carbon tetrachloride, Crompton's equation gives results in better accord with the values obtained from equation 4 than with the thermodynamical results. For these substances at the highest temperatures considered, Crompton's theory gives results differing in no case from those of equation 4 by so much as 0.4 of a calorie, and in several cases the agreement is almost exact. This is splendid confirmation of our belief that in these cases the divergence in the constant of equation, $\frac{L - E_1}{\sqrt[3]{d} - \sqrt[3]{D}} = \text{constant}$, were due to the Biot formula from which the $\frac{\delta P}{\delta T}$ was obtained.

For di-isobutyl, normal heptane, and normal octane, Crompton's equation does not confirm the results of equation 4 when the constants that we have adopted are used, but points instead to lower values for these constants, and we would here call attention to the fact that this indication meets further confirmation (Cf results equations 20, 21 and 25).

For chlor-benzene, brom-benzene, and iodo-benzene, Crompton's theory points to higher constants. This evidence cannot be entirely trusted since the highest measurements for these substances are considerably below the critical temperature.

For stannic chloride, Crompton's equations confirms in a measure the constant adopted. This was a surprise, and suggsets the possibility of an error in the Biot formula used.

For the alcohols and acetic acid, Crompton's equation confirms the belief that in these substances the molecular attraction changes at high temperatures.

To consider the question as to why Crompton's theory does not give correct results at low temperatures we would call attention to the fact that Mr. Crompton could as well have taken the law of the vapor pressure as $PV = P_1V_1$ and have obtained,

$$L = 2\,P_1V_1 \log_e \frac{d}{D}. \qquad [10]$$

Here V_1 is the volume of the liquid and P_1 is the theoretical pressure of the liquid. In calculating this theoretical pressure it will be seen that the equation cancels back to its original form, $2\,RT \log_e \frac{d}{D}$. We have here called attention to the transposition only that the equation might be recognized as identically the same equation with which we have to deal in the Joule-Thomson effect of the free expansion of gases. The

Joule-Thomson energy change is in reality a latent heat—the very same effect of the Crompton equation, only the compression is not carried to liquefaction. That effect has been but little studied and is usually laid entirely upon cohesive forces. This may not be the case, and certainly is not the case when hydrogen, which gives negative results, is considered. We here point out that *if it is experimentally possible, a continuation and extension of the experiments of Joule and Lord Kelvin in connection with the theory of Crompton, should enable Crompton's theory to be understood and correctly modified.*

If the PV curves, Diagrams 1 to 3, be examined in connection with Crompton's equation, it will be noted that Crompton's equation usually gives good agreement with the thermodynamical results at points corresponding to the descending portions of those curves.

THE VARIATION OF THE HEAT OF VAPORIZATION WITH THE TEMPERATURE.

The discussion in this and the previous paper of the data bearing upon the latent heats of vaporization obtained for the twenty-one substances examined cannot have failed to impress one with the wonderful accuracy of the measurements by Profs. Ramsay and Young and by Prof. Young, upon which that data is based. The data upon heats of vaporization here made available is therefore the most extensive and the most accurate yet published. The variation of the latent heat with the temperature has always been a question of interest, and we therefore attempt to show most clearly the manner of this variation.

The function of a portion of the latent heat is well known. It is expended in overcoming the external pressure. The portion so expended can be calculated and neither theoretically nor actually does it appear to be a simple function of the temperature. We have called the energy so expended E, and

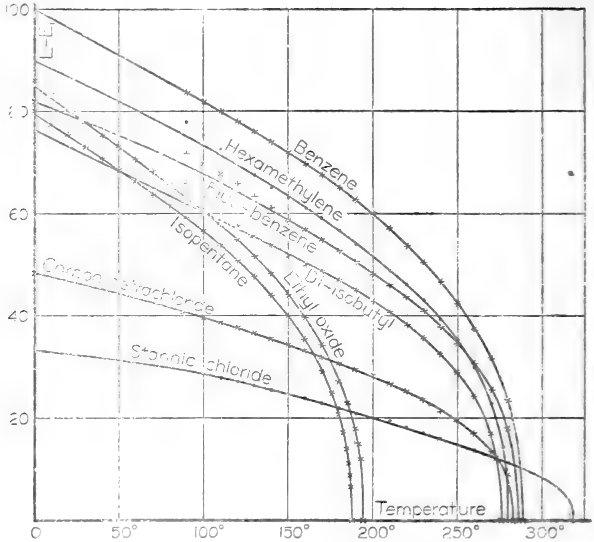

Diagram 8.

Ordinates give internal heat of vaporization in calories.

have given its value for each substance and temperature examined. (See second paper, Tables 2 to 22, under heading E_1).

It has been suggested that $\frac{E_1}{L}$ is a constant, Since E_1 is $0.0_4 31833\ P\,(V - v)$ and $L = 0.0_4 31833\ T\,\frac{\delta P}{\delta T}\,(V - v)$, this would require that $\frac{E_1}{L} = PT\,\frac{\delta P}{\delta T} =$ constant. This relation is not confirmed. Examination shows that E_1 first increases and then decreases with the temperature, while the latent heat, almost invariably, decreases. E_1 thus varies independently of the latent heat and ranges usually between seven and fourteen per cent. of its value.

It was therefore thought best to subtract from the total

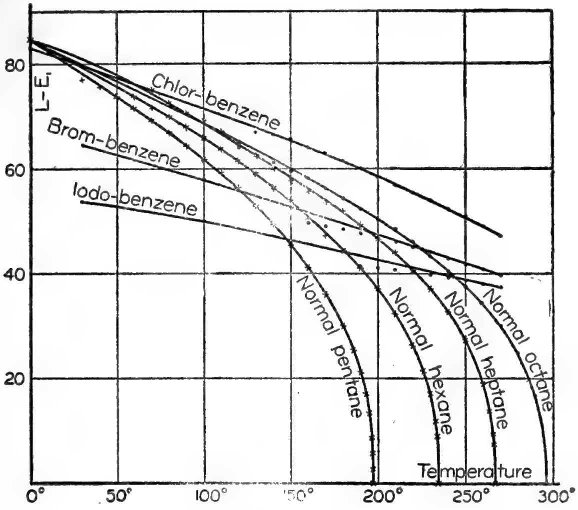

Diagram 9.

Ordinates give internal heat of vaporization in calories.

latent heat this variable amount of energy thus externally expended and to plot the internal latent heat of vaporization against the temperature. The values are given in second paper, Tables 2 to 22, under the heading $L - E_1$. The curves are shown in Diagrams, 8, 9, and 10. The observations are marked with dots, or crosses. The scale needs no explanation except that for water 300 should be added to the ordinates to make the reading as expressed in calories correct.

It will be noted:

1. That the internal latent heat cannot be regarded as a linear function of the temperature except at low vapor pressures and for a limited range of temperature. Water does show a linear variation to 230°, but this is due to Regnault's linear formula from which the values were obtained. The values obtained from Ramsay and Young's observations above

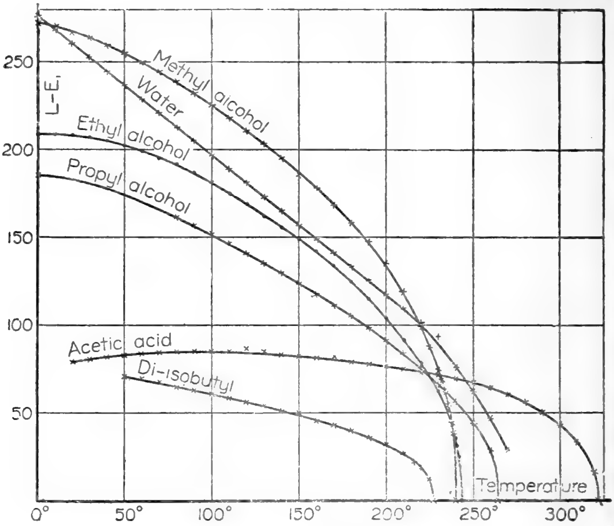

Diagram 10.

Ordinates give internal heat of vaporization in calories.

30° show beyond question that the line for water should al curve perceptibly before that temperature is reached.

2. The curves are all concave towards the temperatu axis. Hexamethylene, di-isobutyl, brom-benzene, and iod benzene would not always be concave if the observations we exactly followed. But the diagrams themselves add strong to evidence already pointed out (p. 147, etc.) in indicating th these values need further study.

3. Except in the case of acetic acid, the internal late heat always decreases with the temperature.

4. Several attempts to find a simple empirical formu connecting the internal latent heat and the temperatu failed. The investigation was not pushed.

SOME RELATIONS RESULTING FROM THE LATENT HEAT EQUATIONS.

By combining equations 6 and 7 we get:

[11] $$P = \frac{\delta P}{\delta T} T - \frac{\mu' (\sqrt[3]{d} - \sqrt[3]{D})}{0.0_4 31833 (V - v)}, \text{ or}$$

[12] $$P = \frac{\delta P}{\delta T} T - \frac{31414 \mu'}{V v^{1/3} + V^{2/3} v^{2/3} + V^{1/3} v}.$$

Equations 11 and 12 are not suitable for calculating accurately the pressure, for that value appears as the difference of two comparatively equal values. We give as an example of such application Table 22. Of the substances we have discussed isopentane is one of the most carefully measured and the agreement is to within the limit of experimental error permitted by the equation. The $\frac{\delta P}{\delta T}$ is obtained from Biot's formula. $\frac{31414 \mu'}{V v^{1/3} + V^{2/3} v^{2/3} + V^{1/3} v}$ is given under the heading "a".

Equation 12 will recall the similar equation:

[13] $$p = bT - a,$$

proposed by Profs. Ramsay and Young[1], where $b = \frac{\delta P}{\delta T}$ and a = constant. The equation is applicable where the volume of the gas is kept constant. "a" has a value dependent upon the volume.

The $\frac{\delta P}{\delta T}$ of equation 12 shows the variation of the vapor pressure of a liquid with a rise in temperature, the volume of the liquid meanwhile undergoing change. The $\frac{\delta P}{\delta T}$ of equation 13 denotes a change in pressure of a gas, the volume

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[1] Phil. Mag., May, 1887. Phil. Mag., August, 1887. Proc. Phys. Soc., 1894-95. Proc. Phys. Soc., Vol. 15. Phil. Mag., April 1899. Proc. Phys. Soc., Vol. 17.

being kept constant. A liquid cannot exist above its critic temperature, and above that point the liquid and its vap are identical. The critical temperature therefore mar the limit for which the $\frac{\delta P}{\delta T}$ of equation 12 can be obtaine but just at that point the $\frac{\delta P}{\delta T}$ of the liquid and the $\frac{\delta P}{\delta T}$ of i vapor at constant volume must be identical. That the $\frac{\delta}{\delta}$ obtained from the Biot formula could not in the nature of t case be accurate at or near the critical temperature we ha already pointed out (second paper, p. 395). That the vari tion we were there led to expect is quantitively equal to t actual variation as found for equation 13 we have subs quently shown (p. 146). It remains to be seen if "*a*" of equ tion 13 corresponds to the function $\frac{31414\,\mu'}{Vv^{1/3} + V^{2/3}v^{2/3} + V^{1/3}v}$ equation 12.

At the critical temperature $v = V$, and therefore we ha at that point,

$$a = \frac{10471\,\mu'}{V^{1/3}}. \qquad [14]$$

Choosing isopentane as being one of the most careful measured substances, we found for μ' the value 105.4 (Tab 25) and V is 4.266. "*a*" therefore becomes 159,400. T values given by Dr. Young[1] at volume 4.3 are 157,880 fro drawn isochors, and 162,890 when calculated from so values of *b*. The agreement in this instance is therefore be regarded as perfect.

That the laws of attraction we have assumed enable t constants of the equation of Ramsay and Young at one poi to be foreseen and calculated is proof of the most convinci nature that the theory of the attraction outlined is corre We are led to believe that, properly modified, the same consi erations will elsewhere be successful in a further calculati

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[1] Proc. Phys. Soc., 1894-95, p. 654.

f these constants. The relation is so full of possibilities ad for its adequate consideration will require so extended an ıvestigation that we postpone the discussion for a separate aper.

Again, combining equations 6 and 8 we obtain:

$$\frac{\delta P}{\delta T} = \frac{287500}{m} \frac{\log \frac{V}{v}}{V - v}. \qquad 5]$$

Owing to the inaccuracy of Crompton's equation at low ıpor pressures at such points equation 15 cannot give accu- te results. But as the critical temperature is approached e believe that this equation offers the most accurate method t available for finding the $\frac{\delta P}{\delta T}$, giving results far better an could be obtained from direct observations of the pres- re even when the observations are afterwards smoothed.

In Table 23 we apply the equation to isopentane com- ring the results obtained by its aid with those obtained m Biot's formula.

At the critical temperature the fraction $\frac{\log \frac{V}{v}}{V - v}$ assumes the leterminate form $\frac{0}{0}$. Evaluating by diffentiating the merator and denominator we find the limit approached at critical temperature to be $\frac{0.4343}{V}$, 0.4343 being the modu- of the Naperian system of logarithms. Therefore we ve at the critical temperature,

$$\frac{\delta P}{\delta T} = \frac{124860}{mV}, \qquad]$$

ery simple relation. For isopentane we thus get the ues of $\frac{\delta P}{\delta T}$ as 405.9, a result in exact accord with the ues 397 to 407 as given by Dr. Young[1], and thus confirm-

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[1] Proc. Phys. Soc., 1894-95, p. 950.

ing every conclusion we have hitherto drawn relative to the value of $\frac{\delta P}{\delta T}$ at this point.

Combining equation 16 with 12 and remembering that at the critical temperature $V = v$ we have,

$$[17] \qquad P = \frac{124860\,T}{mV} - \frac{10471\,\mu'}{V^{4/3}}.$$

Applying this equation to isopentane, we have, $V = 4.266$, $m = 72.1$, $T = 460.8$, $\mu' = 105.4$, and the pressure thus calculated is 27600 against 25000 observed, an agreement well within the limit of experimental error, since the pressure is found as a difference.

A more general equation is obtained by combining equations 7 and 8 to obtain

$$[18] \qquad P = \frac{31414}{V - v} \left\{ \frac{9.1522}{m} T \log \frac{V}{v} - \mu' \left(\sqrt[3]{d} - \sqrt[3]{D} \right) \right\},$$

an equation which, owing to the divergence shown by Crompton's theory is not applicable to low pressures.

We have purposely omitted all reference to those equations connecting the latent heat with the specific heat of liquid or vapor, as it is our purpose at a future time to point out a relation existing between the specific heat of solid, liquid, and vapor, and to discuss such equations in that connection.

A FURTHER APPLICATION OF CROMPTON'S THEORY TO VERIFY THE PROPOSED LAW OF MOLECULAR ATTRACTION.

Following a line of argument already advanced[1], if we consider any gas it is reduced to the liquid state by pressure and by the molecular attraction. In nature the two, pressure and attraction, act jointly and continuously. But theoretically we can separate their action, since mechanically all forces are independent of each other. Legitimately then, we can consider a liquid at its critical temperature as reduced to that

[1] Jour. Phys. Chem., April, 1902, p. 223.

density: First, by the action of a pressure; second, by the action of molecular attraction. Accordingly the theoretical density of the gas at its critical temperature and under its critical pressure was calculated. *The gas would be reduced to that condition if there were no molecular attraction. The remainder of the condensation, to the actual density, must be the work of the attraction alone.*

The theoretical critical density can be calculated by the equation,

$$[19] \qquad D = 0.0_4 16014 \frac{Pm}{T}.$$

If the attraction obeys the law assumed we can use equation 2 to calculate the energy necessary to overcome the attraction and expand the gas from its observed to its theoretical density. If to the energy so calculated we add the energy necessary to overcome the external pressure during the change in volume, we have the total energy, $\lambda + E_1$, required by the change. The equation will become,

$$[20] \quad \lambda + E_1 = \mu' (\sqrt[3]{d} - \sqrt[3]{D}) + 0.0_4 31833\, P\left(\frac{1}{D} - \frac{1}{d}\right) \text{Cals.}$$

By Crompton's theory we can calculate the energy necessary to change the gas from its observed to its theoretical density as if the change were produced by pressure alone, the equation being:

$$[21] \qquad L = \lambda + E_1 = \frac{9.1522}{m} T \log \frac{d}{D} \text{ Cals.}$$

In these equations T is the critical temperature, d denotes the critical density, and D is the theoretical density of the vapor at the critical point.

The results of equation 20 are given in Table 24 under heading Mills. The results from equation 21 are given under the heading Crompton. The difference is also given The agreement is as perfect as could be desired. The difference is usually less than one calorie and amounts to a divergence of more than four per cent. only in the case of normal octane and the associated substances. (To these latter neither theory is applicable.)

With the three alcohols others have concluded that at the critical temperature *there is no association.* With them the molecular attraction, it will be recalled, changed with the temperature. Using the values of μ', obtained nearest the critical temperature, where the effect of the association could be assumed *nil*, we obtained the last values given, which are in good accord with the results given by Crompton.

In Table 24 the critical data, except for water, are from the measurements of Profs. Ramsay and Young or Dr. Young. References have been given (second paper).

There is nothing in the method adopted to prevent the application of equations 20 and 21 to other points than the critical temperature. Had the equations been combined, an equation similar to equation 18 would have been produced, and the above results may be regarded as but a special application of that equation.

EXTENSION OF THE THEORY TO THE ENERGY RELATIONS AT THE CRITICAL TEMPERATURE.

Solving equation 6 of the first paper[1] we get:

$$\mu = c\frac{L - E_1}{\sqrt[3]{d} - \sqrt[3]{D}}\sqrt[3]{m} = c\mu'\sqrt[3]{m} \qquad [22]$$

where c is the same constant for all non-associated substances, and m is the molecular weight. $\frac{L - E_1}{\sqrt[3]{d} - \sqrt[3]{D}}$ we have shown to be a constant for any particular substance, have called this constant μ', and have given the average constants for the substances examined (Table 25). μ represents the absolute attraction at unit distance from a molecule and must be regarded as an exceedingly important and a constant property of the molecule. The values obtained for $\frac{\mu}{c}$ are given in Table 25.

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[1] Jour. Phys. Chem., 1902, 4, p. 209.

We would here call attention to the fact that for bodies of similar constitution and closely related chemically the values of μ may be the same, though the observations are not sufficiently extended to permit of any definite conclusion. Thus:

Normal pentane, - - - - -	457.3
Normal hexane, - - - - -	454.2
Normal heptane, - - - - -	458.6
Normal octane, - - - - -	451.1
But isopentane, - - - - -	438.6

It is well also to note that for the associated substances, water, the alcohols, and to a less degree for acetic acid where it is less associated, the values for μ are greatly larger than for the other substances examined, and this very large attraction is suggestive in view of the conclusion drawn in the second paper that quite possibly the molecular association of these substances was caused by the molecular attraction.

Resuming a line of argument followed in the first paper (p. 228) we can test our conclusions further. In a gas indefinite expansion takes place as the pressure is decreased. This shows that the attraction between the molecules cannot be great enough to make the paths of the molecules closed curves. In a liquid, while undoubtedly many molecules whose velocity is above the average molecular velocity, are continually flying away from the surface, yet it must certainly be the case that most of the molecules are drawn back by the molecular attraction. There must be for each substance a certain temperature at which the molecular attraction, without outside pressure, is just strong enough to overbalance the kinetic translational energy of the average particle and cause it to return to the liquid or solid substance. At this point, if the attraction varies inversely as the square of of the distance between the molecules, we will have from mechanics,

[23] $$V'^2 = 2\frac{\mu}{R},$$

where V′ is the molecular velocity and R is the distance apart of the molecules. μ is the absolute attraction at unit distance.

It is a common text book idea that at the critical temperature the kinetic energy of the molecules of a liquid (gas) under the critical pressure just balances the attraction. The idea rests on the diminution and final disappearance of surface tension at the critical temperature, and the fact that a liquid at its critical temperature may be changed to a gas without the addition of external energy, i. e., by an infinitesimal change in pressure, the heat of vaporization being zero. It must then be at this point that equation 23 will hold good. Putting therefore for the molecular velocity, V′, its value at this point $\sqrt{\frac{3RcT}{m}}$ (derived as usual, R*c* being 83,250,000) and for R its value $c\sqrt[3]{\frac{m}{d}}$, the constant *c* being unknown, but equal for all for all substances, we get finally,

$$\mu = c'\frac{T}{m}\sqrt{\frac{m}{d}}. \qquad [24]$$

In this equation T and *d* denote respectively the critical temperature and density, and *c′* is the same for all substances. Using the values for the critical constants as given in Table 24 we obtain for $\frac{\mu}{c'}$ the values given in Table 25.

Now if our ideas are correct and the absolute attraction μ, given in equations 22 and 24 are the same, and correctly measured, we have a right to combine these equations and get:

$$\frac{\frac{\mu}{c}}{\frac{\mu}{c'}} = \text{constant} = \frac{\frac{L - E_1}{\sqrt[3]{d} - \sqrt[3]{D}}}{\frac{T}{m}\sqrt[3]{\frac{m}{d}}}, \text{ or,}$$

$$\frac{m\mu'\sqrt[3]{d}}{T} = \text{constant}, \qquad [25]$$

where T must be the critical temperature and d must be the critical density.

If therefore the values of $\frac{\mu}{c}$ given in Table 25 be divided by the values of $\frac{\mu}{c'}$ given in the same table, the results should prove constant for all non-associated substances. The result of this division is given in Table 25.

The mean value for the non-associated substances is 10.76. Since the values for μ' are uncertain by about two per cent., and since the critical data cannot be measured accurately, the close agreement can be regarded as exceedingly satisfactory. A review of the data leads the author to believe that isopentane and normal octane are the only variations that are not due largely to the values adopted for μ'.

Associated substances, *a priori*, could not agree with the equations deduced and they do not. But considering them more particularly, it will be seen that if at the critical temperature the molecular association had vanished (as is said to be the case for the alcohols), equation 24 would hold. If instead of the average value obtained for μ' at the lower temperatures, we use the values for the constant obtained near the critical temperature, equation 22 should also hold, simultaneously with equation 24. For water the data near the critical temperature is lacking, but making use of the proper values for the alcohols, we obtain the results obtained in Table 25. These results would evidently be somewhat better if the observtions of μ' could have been obtained yet nearer the critical point, and we are thus led to regard these associated substances as giving a very remarkable confirmation of the theory.

It should be noted that the constant obtained from equation 25 and given in Table 25 is just one-half of the constant obtained in Trouton's formula, $\frac{mL}{T} =$ constant, where T is the boiling point of a substance. That there is a reason for this fact we propose later to show in connection with a paper applying the law of attraction to the boiling point.

In conclusion we again point out that we are indebted to Drs. Ramsay and Young and to Dr. Young, for nearly every measurement used in this article. And we would again express our great appreciation of the accuracy of these measurements and acknowledge our obligation to them.

SUMMARY.

1. Several facts bearing upon the results of the last paper are discussed. These facts confirm the law of attraction assumed by making it most clear that $\frac{L - E_1}{\sqrt[3]{d} - \sqrt[3]{D}}$ does equal a constant (designated μ'), for normally constituted substances, and that the equation is applicable with equal exactness in the immediate neighborhood of the critical temperature.

2. An equation, $L = 2RT \log_e \frac{d}{D}$, proposed by Mr. H. Crompton was investigated, and it was found that at low temperatures, where the vapor pressure is small, the results given by the equation are invariably, and usually very considerably, too large. But at higher temperatures the results are correct.

3. Crompton's equation was shown at the critical temperature to give results confirming the law of attraction assumed. (Equations 21 and 22.)

4. It was shown that, $\frac{\delta P}{\delta T} = \frac{287500}{m} \frac{\log \frac{V}{v}}{V - v}$, within certain limits.

5. It was shown that at the critical temperature the following relations hold true:

[*a*] $$P = \frac{\delta P}{\delta T} T - \frac{10471\, \mu'}{V^{4/3}},$$

[b] $$\frac{\delta P}{\delta T} = \frac{124860}{mV},$$

[c] $$\frac{m \mu' \sqrt[3]{d}}{T} = \text{constant},$$

the last being an interesting confirmation of the law of attraction assumed.

6. It was shown that at the critical volume "*a*" of the equation, $p = bT - a$, becomes identical with the term, $\frac{10471 \mu'}{V^{4/3}}$.

7. The variation of the latent heat of vaporization with the temperature is discussed.

University of North Carolina,
August, 1904.

ADDENDUM.

Since this paper was written, a letter has been received from Dr. Young, giving the values of the $\frac{\delta P}{\delta T}$ for ethyl oxide. The pressures given in the original paper are correct as are the values of the $\frac{\delta P}{\delta T}$ below 180° C. The corrected values above that temperature are given below, together with the corrected values of the heat vaporization and of μ'.

Temp.	$\frac{\delta P}{\delta T}$ corrected	L	$L - E_1$	μ'
185°	354.9	26.18	22.36	97.7
190	374.1	19.21	16.42	96.4
192	382.2	14.66	12.52	93.5
193	385.8	11.17	9.53	90.7
194	389.8	——	——	——
194.45	391.6	——	——	——

Dr. Young gives 194.45° as probably very nearly the true critical temperature, and 3.814 as the true critical volume of a gram. By interpolation of the results given by Profs. Ramsay and Young (Phil. Mag. May, 1887, p. 441) for the equation $P = bT - a$, the true value for the $\frac{\delta P}{\delta T}$ at this volume appears to be 436. Thus the $\frac{\delta P}{\delta T}$ from Biot's formula at the critical temperature is about ten per cent. too low, an amount which is not quite sufficient to explain the decrease in the value of μ' at the higher temperatures. But above 180° C, owing to hydrolysis of the methyl salicylate used as a heating jacket, the data is somewhat uncertain.

It should be noticed that equation 16 of the present paper gives 441.9 as the value of the $\frac{\delta P}{\delta T}$ at the critical temperature, a result which agrees well with the value 436 given below, thus confirming what has been said as to the accuracy of that equation.

November 1, 1904.

TABLE 1.
Ethyl Oxide.

Temperature.	Heat of Vaporization.			PV/1000.
	Ther.	Mills.	Cromp-ton.	
0	93.27	91.59*	99.42	224
20	87.90	87.94	93.42	237
40	83.18	83.85	87.62	247
60	78.84	79.46	81.95	255
80	73.95	74.49	76.03	259
100	68.35	68.89	69.76	260
120	62.63	62.41	62.79	256
140	55.52	55.05	55.04	247
160	45.99	45.98	45.71	228
180	31.58	32.54	32.19	192
190	20.90	20.58	20.25	156
192	17.10	16.11	15.84	143
193	13.67	12.61*	12.36	132
194	------	------	------	110

TABLE 2.
Di-isopropyl.

Temperature.	Heat of Vaporization.			PV/1000.
	Ther.	Mills.	Cromp-ton.	
0	85.11	85.40	94.24	198
60	76.90	76.42	79.91	234
80	72.86	72.66	75.13	241
100	68.28	68.45	70.15	243
120	63.57	63.85	64.98	244
140	58.58	58.75	59.46	242
160	52.70	52.87	53.23	234
180	45.86	45.90	45.99	221
200	37.15	37.16	37.05	201
210	31.09	31.31	31.16	185
220	22.14	22.79	22 59	159
225	14.57	15.40	15.23	137
227.35	------	------	------	96.8

TABLE 3.
Di-isobutyl.

Temperature.	Heat of Vaporization.			PV/1000.
	Ther.	Mills.	Cromp-ton.	
0	80.99	78.62*	91.35	149
100	69.25	67.52*	69.46	196
120	63.79	64 15	64.99	195
140	59.84	60.70	60.78	197
160	56.30	57.01	56.57	199
180	53.05	53.10	52.28	201
200	48.83	48.51	47.43	197
220	43 80	43.09	41.85	189
240	37 37	36.39	35.08	175
260	27.93	27.08	25.88	151
270	19.54	19.29	18.33	128
274	14.24	14.22	13.46	115
276.8	------	------	------	78.8

TABLE 4.
Isopentane.

Temperature.	Heat of Vaporization.			PV/1000.
	Ther.	Mills.	Cromp-ton.	
0	88.86	87.45*	95.92	236
20	82 91	83.52	89.98	243
40	78.69	79.44	84.46	252
60	74.56	75.00	78.96	260
80	70.00	70.12	73.26	265
100	64.78	64.56	67.09	265
120	58.62	58.19	60.16	259
140	51.07	50.52	52.00	246
160	41.27	40.83	41.84	223
180	24.65	25.05	25.54	177
185	16.47	17.17	17.46	153
187	10.43	11.08	11.25	135
187.4	8.07	8.69	8.81	128
187.8	------	------	------	107

TABLE 5.

Normal Pentane.

Temperature.	Heat of Vaporization.			PV /1000.
	Ther.	Mills.	Crompton.	
0	93.36	92.38	101.18	236
40	83.63	84.58	89.47	255
60	80.04	80.29	83.98	266
80	75.30	75.39	78.18	271
100	69.87	69.88	71.90	271
120	64.48	63.85	65.34	269
140	56.58	56.31	57.30	256
160	47.42	47.27	47.89	237
180	35.01	35.16	35.43	207
190	24.68	25.38	25.49	178
195	15.66	16.60	16.63	151
197	6.55	7.15	7.14	125
197.15	3.11	3.41	3.41	116
197.2				108

TABLE 6.

Normal Hexane.

Temperature.	Heat of Vaporization.			PV /1000
	Ther.	Mills.	Crompton.	
0	90.98	90.33	100.82	198
60	80.82	81.09	84.86	228
80	77.55	77.43	79 90	238
100	73.65	73 37	74.84	244
120	69.38	68.91	69.67	248
140	63.96	63.75	63.98	247
160	57.63	57.78	57.61	239
180	50.93	51.04	50.59	228
200	42.75	42.78	42.16	211
220	30.37	30.82	30.18	179
230	19.73	20.56	20.04	149
234	10.44	11.26	10.94	123
234.8				95.7

TABLE 7

Normal Heptane.

Temperature.	Heat of Vaporization.			PV / 1000.
	Ther.	Mills.	Crompton.	
0	89.86	89.10	100.25	170
80	79.52	79.06	80.66	214
100	75.96	75.76	76.12	222
120	71.79	72.06	71.47	226
140	67.19	67.94	66.69	228
160	62.74	63.47	61.73	229
180	58.52	58.63	56.63	227
200	53.17	52.98	50.83	220
220	46.46	46 09	43.92	207
240	37.45	37.12	35.11	185
260	21.90	22.33	20.90	144
264	15.84	16.48	15.38	127
266.5	8.50	9.15	8.52	107
266.9				87.0

TABLE 8.

Normal Octane.

Temperature.	Heat of Vaporization.			PV / 1000.
	Ther.	Mills	Crompton.	
0	89.46	85.55*	99 98	149
120	70.27	71.55*	71.58	197
140	67.56	68.38	67.52	204
160	64.82	64.96	63.45	210
180	60.99	61.07	59.06	211
200	56.87	56.71	54.38	210
220	52.03	51.72	49.20	204
240	45.97	45.65	43.10	193
260	39.14	38.57	36.15	179
280	28.26	28.13	26.12	152
290	19.10	19.47	17.97	128
296.2				80.5

TABLE 9.

Benzene.

Temperature.	Heat of Vaporization.			PV/1000.
	Ther.	Mills	Crompton.	
0	107.05	107.25	123.89	218
80	94.40	95.75*	102.49	277
100	91.05	92.07*	97.44	286
120	87 36	88.00	92.32	293
140	83.48	83.72	87.27	300
160	79.20	79.18	82.09	305
180	74.53	74.24	76.69	307
200	69.01	68.45	70.43	301
220	62.32	61.74	63.34	290
240	54.21	53.74	54.96	271
260	43.76	43.57	44.40	244
280	27.43	27.79	28.17	197
288.5	--------	--------	--------	102.5

TABLE 10.

Hexamethylene.

Temperature.	Heat of Vaporization.			PV/1000.
	Ther.	Mills.	Crompton.	
0	96.22	97.13	111.80	203
100	83.71	82.82	87.47	267
120	78.69	78.89	82.58	270
140	73.60	74.56	77.53	272
160	69.68	70.19	72.61	275
180	65.15	65.27	67.25	274
200	59.37	59.60	61.21	267
220	53.56	53.27	54.56	258
240	45.76	45.37	46.31	240
260	35.16	34.84	35.42	211
270	26.72	26.76	27.14	196
277	16.85	17.34	17.53	157
279	11.78	12.34	12.45	142
279.95	--------	--------	--------	111

TABLE 11.

Fluo-benzene.

Temperature.	Heat of Vaporization.			PV/1000.
	Ther.	Mills.	Crompton.	
0	87.39	88.36	102.66	177
80	80.06	79.05	84.62	224
100	77.09	76.06*	80.38	233
120	73.21	72.68	76.02	239
140	68.50	68.91	71.46	240
160	64.37	64.96	66.92	242
180	60.09	60.65	62.17	241
200	55.24	55 76	56.89	236
220	50.28	50.32	51.18	230
240	44.03	43.78	44.34	216
260	35.74	35 30	35.59	196
280	20.95	21.15	21.18	153
286.55	--------	--------	--------	82.6

TABLE 12.

Chlor-benzene.

Temperature.	Heat of Vaporization.			PV/1000.
	Ther.	Mills.	Crompton.	
0	87.72	87.25	107.14	152
140	73.37	74.12	79.06	218
160	71.26	71.56	75.63	226
180	68.77	68.75	72.08	232
200	65.65	65.58	68.34	235
220	62.60	62.18	64.46	236
240	59.65	58.48*	60.30	235
260	56.06	54.24*	55.66	231
270	53.95	51.88*	53.10	------
280	--------	--------	--------	223
360.7	--------	--------	--------	81.3

Table 13.

Brom-benzene.

Temperature.	Heat of Vaporization.			PV / 1000.
	Ther.	Mills.	Cromp-ton.	
30	68.68	65.78*	79.45	121
100	62.58	61.77	68.76	148
160	54.69	56.55*	60.39	160
180	53.80	54.80	58.02	167
200	52.27	52.82	55.47	172
220	50.41	50.61	52.80	175
240	48.29	48.24	50.02	176
260	46.30	45.72	47.18	177
270	45.03	44.32	45.62	
280	—	—	—	174
397.0	—	—	—	59.5

Table 14.

Iodo-benzene.

Temperature.	Heat of Vaporization.			PV / 1000.
	Ther.	Mills.	Cromp-ton.	
30	56.70	55.99	68.77	92.8
100	53.68	53.32	60.08	114
200	45.34	47.01*	49.36	135
220	44.94	45.64	47.57	142
240	43.70	44.02	45.54	144
260	42.50	42.25	43.45	146
270	41.85	41.27	42.31	
280	—	—	—	147
448	—	—	—	49.7

Table 15.

Carbon Tetrachloride.

Temperature.	Heat of Vaporization.			PV / 1000.
	Ther.	Mills.	Cromp-ton.	
0	51.87	52.50	60.72	111
100	44.20	44.67	47.62	143
120	42.24	42.64	45.13	147
140	40.26	40.51	42.61	150
160	37.95	38.15	39.96	151
180	35.40	35.53	37.08	150
200	32.61	32.58	33.92	147
220	29.45	29.19	30.31	142
240	25.56	25.15	26.05	134
260	20.07	19.73	20.36	119
280	10.43	10.47	10.75	91.2
283.15	—	—	—	52.3

Table 16.

Stannic Chloride.

Temperature.	Heat of Vaporization.			PV / 1000.
	Ther.	Mills.	Cromp-ton.	
0	35.38	35.18	42.19	65.4
100	31.40	30.95	33.29	86.5
120	30.02	29.81	31.67	89.7
140	28.52	28.56	30.02	92.3
160	26.86	27.19	28.38	94.1
180	24.89	25.69	26.66	94.7
200	22.97	24.08*	24.90	94.8
220	20.89	22.28*	22.99	93.9
240	18.60	20.25*	20.88	91.5
260	16.03	17.89*	18.46	87.1
280	13.08	15.06*	15.52	80.3
318.7	—	—	—	32.6

TABLE 17.

Water.

Temperature.	Heat of Vaporization.			PV /1000
	Ther.	Mills.	Cromp-ton.	
0	606.5	574.6	738.4	965
20	592.6	571.2	709.8	1022
40	578.6	565.8	682.4	1082
60	564.7	558.4	656.0	1142
80	550.6	549.4	630.6	1202
100	536.5	538.9	606.5	1260
120	522.3	526.4	582.7	1304
140	508.0	512.8	559.4	1347
160	493.6	498.1	536.4	1404
180	479.0	481.3	513.3	1435
200	464.3	463.8	490.7	1478
220	449.4	445.2	467.4	1523
240	423.8	423.5	442.1	1533
260	394.0	399.3	414.2	1514
270	374.5	385.4	398.5	1486
364.3	--------	--------	--------	345

TABLE 18.

Methyl Alcohol.

Temperature.	Heat of Vaporization.			PV /1000.
	Ther.	Mills.	Cromp-ton.	
0	289.2	289.4	324.4	527
20	284.5	283.1	307.2	561
40	277.8	275.8	290.3	593
60	269.4	266.9	273.6	621
80	259.0	256.8	256.9	643
100	246.0	245.1	240.0	658
120	232.0	231.7	222.7	665
140	216.1	216.6	205.0	664
160	198.3	199.4	185.8	652
180	177.2	179.3	164.9	629
200	151.8	154.4	140.0	585
220	112.5	118.5	106.2	494
230	84.5	92.2	81.9	426
236	61.7	68.9	61.0	372
238.5	44.2	51.1	45.0	326
240	--------	--------	--------	220

TABLE 19.

Ethyl Alcohol.

Temperature.	Heat of Vaporization.			PV/1000.
	Ther.	Mills.	Cromp-ton.	
0	220.9	228.4	238.0	369
20	220.6	223.9	224.3	396
40	218.7	218.3	210.8	423
60	213.4	211.4	197.5	446
80	206.4	203.4	184.2	467
100	197.1	194.4	171.2	483
120	184.2	183.6	157.9	490
140	171.1	171.2	144.5	494
160	156.9	157 7	130.7	491
180	139.2	141.7	115.6	474
200	116 6	121.7	97.8	437
220	88.2	94.6	74.8	377
240	40.3	45.8	35.5	265
242.5	22.1	26.5	20.3	219
243.6	--------	--------	--------	167

TABLE 20.

Propyl Alcohol.

Temperature.	Heat of Vaporization.			PV/1000.
	Ther.	Mills.	Cromp-ton.	
0	194.4	190.8	200.9	284
80	173.0	172.4	153.7	360
100	164.0	165.2	142.7	373
120	153.0	157.0	132.0	379
140	142.4	147.9	121.5	381
160	129.0	137.6	110.7	381
180	116.3	125.8	99.9	373
200	102.2	112.7	88.2	362
220	85.3	96.6	74.7	336
240	63.4	75.3	57.5	290
260	33.5	41.4	31.2	224
263.7	--------	--------	--------	137

TABLE 21.

Acetic Acid.

Temperature.	Heat of Vaporization.			PV/1000	Temperature.	Heat of Vaporization.			PV/1000.
	Ther.	Mills	Cromp-ton.			Ther.	Mills.	Cromp-ton.	
20	84.05	--------	184.80	153	200	85.55	--------	115.73	284
40	87.02	--------	176.94	173	220	82.02	--------	106.72	286
60	89.69	--------	169.46	192	240	78.18	--------	97.21	288
80	91.59	--------	162.05	211	260	72.26	--------	86.44	284
100	92.32	--------	154.62	228	280	63.39	--------	73.61	272
120	94.38	--------	147.20	246	300	48.95	--------	56.86	243
140	91.83	--------	139.58	259	310	37.77	--------	44.37	216
160	89.63	--------	131.82	269	320	18.04	--------	22.67	164
180	87.71	--------	123.95	278	321.65	--------	--------	--------	124

TABLE 22.

Isopentane.

Temperature.	$\frac{\delta P}{\delta T}$	$\frac{\delta P}{\delta T}T$	a	Pressure.	
				Calcu-lated.	Biot.
0	11.16	3047	2742	305	258
20	21.04	6165	5639	526	573
40	35.66	11162	10139	1023	1131
60	55.73	18558	16634	1924	2036
80	81.85	28893	25541	3352	3401
100	114.70	42783	37310	5473	5354
120	155.18	60986	52480	8506	8040
140	204.42	84425	71920	12505	11620
160	264.0	114312	96810	17502	16285
180	335.9	152163	132410	19753	22262
187.8	367.8	169480	159420	10060	25005

TABLE 23.

Isopentane.

Temperature.	$\log\frac{V}{v}$	$V-v$	$\frac{\log\frac{V}{v}}{V-v}$	$\frac{\delta P}{\delta T}$ from Equati'n 15	$\frac{\delta P}{\delta T}$ from Biot
0	2.768	915.8	.003022	12.05	11.16
20	2.419	422.4	.005725	22.83	21.04
40	2.126	221.5	.009598	38.27	35.66
60	1.868	126.2	.01480	59.00	55.73
80	1.635	76.1	.02147	85.61	81.85
100	1.417	47.56	.02980	118.82	114.70
120	1.206	30.20	.03993	159.22	155.18
140	.9920	19.00	.05221	208.16	204.42
160	.7612	11.34	.06712	267.6	264.0
180	.4442	5.09	.08728	348.0	335.9
187.4	.1508	1.503	.1003	399.9	366.4
187.8	--------	--------	.1018	405.9	367.8

TABLE 24.

Substance.	Molecular Weight.	μ'	Critical.			Theoretical Density.
			Temperature.	Pressure	Density.	
Ether	74.08	104.4	194.0	27060	.2463	.06873
Di-isopropyl	86.11	98.08	227.35	23330	.2411	.06430
Di-isobutyl	114.14	86.30	276.8	18640	.2366	.06197
Isopentane	72.10	105.4	187.8	25005	.2344	.06266
Normal pentane	72.10	109.9	197.2	25063	.2324	.06157
Normal hexane	86.11	102.85	234.8	22433	.2343	.06093
Normal heptane	100.13	98.75	266.9	20399	.2344	.06057
Normal Octane	114.14	93.00	296.2	18734	.2327	.06015
Benzene	78.05	109.5	288 5	36395	.3550	.08100
Hexamethylene	84.10	103.6	279.95	30234	.2733	.07365
Fluo-benzene	96.09	85.60	286.55	33912	.4107	.09325
Chlor-benzene	112.5	81.19	360.7	33962	.4179	.09654
Brom-benzene	157.0	56.12	397.0	33912	.5695	.12730
Iodo-benzene	203.9	44.40	448.0	33912	.6826	.1536
Carbon tetrachloride	153.8	44.09	283.15	34180	.6536	.1514
Stannic chloride	260.8	26.04	318 7	28080	.8621	.1982
Water	18.02	553.3	364.3	148200	.429	.06707
Methyl alcohol	32.03	305.0	240.0	59759	.2715	.05974
Ethyl alcohol	46.05	241.2	243.6	47700	.2857	.06809
Propyl alcohol	60.06	199.2	263.7	38120	.2778	.06830
Acetic Acid	60.03	130.0	321.65	43480	.3506	.07025
Methyl alcohol	-------	259.4	-------	-------	-------	-------
Ethyl Alcohol	-------	197.2	-------	-------	-------	-------
Propyl alcohol	-------	157.0	-------	-------	-------	-------

TABLE 24—Continued.

Substance.	E_1	$d^{1/3}—D^{1/3}$	λ	Latent Heat		Δ
				Mills.	Crompton.	
Ether	9.03	.2173	22.69	31.72	31.98	—.26
Di-isopropyl	8.46	.2218	21.75	30.21	30.52	—.31
Di-isobutyl	7.07	.2228	19.23	26.30	25.65	.65
Isopentane	9.30	.2194	23.11	32.41	33.51	—1.10
Normal pentane	9.52	.2199	24.17	33.69	34.42	—.73
Normal hexane	8.67	.2230	22.93	31.60	31.57	.03
Normal heptane	7.95	.2239	22.11	30.06	29.00	1.06
Normal octane	7.35	.2233	20.77	28.12	26.82	1.30
Benzene	11.04	.2754	30.14	41.18	42.26	- 1.08
Hexamethylene	9.55	.2298	23.80	33.35	34.27	—.92
Fluo-benzene	8.95	.2898	24.81	33.76	34.30	—.54
Clor-benzene	8.62	.2889	23.45	32.07	32.81	—.74
Brom-benzene	6.59	.3258	18.28	24,87	25.41	—.54
Iodo-benzene	5.45	.3450	15.32	20.77	20.97	—.20
Carbon tetrachloride	5.52	.3348	14.76	20.28	21.02	—.74
Stannic chloride	3.47	.3686	9.60	13.07	13.25	—.18
Water	59.29	.3479	192.5	251.8	260.9	—9.1
Methyl alcohol	24.84	.2566	78.26	103.10	96.35	6.75
Ethyl alcohol	16.99	.2502	60.35	77.34	63.94	13.50
Propyl alcohol	13.39	.2437	48.55	61.94	49.81	12.13
Acetic acid	15.75	2925	38.02	53.77	63.27	—9.50
Methyl alcohol	-------	-------	66.55	91.39	-------	—4.96
Ethyl alcohol	-------	-------	49.34	66.33	-------	2.39
Propyl alcohol	-------	-------	38.25	51.64	-------	1.83

TABLE 25.

Substance.	μ'	$\frac{\mu}{c}$	$\frac{\mu}{c'}$	Ratio of $\frac{\mu}{c}$ to $\frac{\mu}{c'}$
Ether	104.4	438.5	42.23	10.38
Di-isopropyl	98.08	433.1	41.23	10.51
Di-isobutyl	86.30	418.6	37.78	11.08
Isopentane	105.4	438.6	43.14	10.17
Normal pentane	109.9	457.3	44.15	10.36
Normal hexane	102.85	454.2	42.24	10.75
Normal heptane	98.75	458.6	40.62	11.29
Normal octane	93.00	451.1	39.34	11.47
Benzene	109.5	468.0	43.415	10.78
Hexamethylene	103.6	453.8	44.38	10.23
Fluo-benzene	85.60	392.3	35.86	10.94
Chlor-benzene	81.19	391.9	36.38	10.77
Brom-benzene	56.12	302.8	27.76	10.91
Iodo-benzene	44.40	261.3	23.64	11.05
Carbon tetrachloride	44.09	236.2	22.32	10.58
Stannic chloride	26.04	166.4	15.23	10.98
Water	553.3	1450.8	123.00	11.79
Methyl alcohol	305.0	968.6	78.56	12.34
Ethyl alcohol	241.2	864.5	61.04	14.16
Propyl alcohol	199.2	780.1	53.64	14.54
Acetic acid	130.0	509.1	55.00	9.26
Methyl alcohol	259.4	823.8		10.49
Ethyl alcohol	197.2	706.8		11.58
Propyl alcohol	157.0	614.8		11.46

VOL. XXI MARCH 1905 NO. 1

JOURNAL

OF THE

Elisha Mitchell Scientific Society

[redacted]

ISSUED QUARTERLY

PUBLISHED BY THE UNIVERSITY OF NORTH CAROLINA.

CHAPEL HILL, N. C., U. S. A.

TO BE ENTERED AT THE POSTOFFICE AS SECOND CLASS MATTER

Elisha Mitchell Scientific Society.

CONTENTS.

Journal of the Elisha Mitchell Scientific Society—Quarterly. Price $2.00 per year; single numbers 50 cents. Most numbers of former volumes can be supplied. Direct all correspondence to the Editors, at University of North Carolina, Chapel Hill, N. C.

JOURNAL

OF THE

ELISHA MITCHELL SCIENTIFIC SOCIETY.

(Official Publication of the N. C. Academy of Science)

VOL. XXI MARCH, 1905 NO. 1

A DESCRIPTIVE CATALOGUE OF THE MAMMALS OF NORTH CAROLINA, EXCLUSIVE OF THE CETACEA.

BY C. S. BRIMLEY.

This list is intended to represent our present knowledge of the occurrence and distribution of the land Mammals found within the limits of the State of North Carolina, together with keys to the orders, families and genera, and brief descriptions of the various species.

The keys are mainly adapted from Mr. G. S. Miller's "Key to the Land Mammals of Northeastern North America," but some use has also been made of Dr. Jordan's well known "Manual of the Vertebrates."

The material on which this list is based is as follows:

I. COLLECTIONS OF MAMMALS MADE IN NORTH CAROLINA.

1. A collection of the smaller mammals of Bertie county made for the author and his brother by Mr. T. A. Smithwick, of Walke, and Mr. J. W. P. Smithwick, of Sans Souci, in 1892, 1893, and 1894. The collection comprised nineteen species, the largest being the Flying Squirrel and a list of them was published by the author in the *American Naturalist*, March, 1897.

2. Specimens received from Mr. J. S. Cairns (now deceased),

of Weaverville, Buncombe county, comprising sixteen species of the smaller mammals of that region, the largest being the Red Squirrel. A Starnosed Mole was also received from Mrs. Cairns after her husband's death. (Collecting was done from about 1891 to 1894.)

3. In 1872 Dr. Elliott Coues collected a number of natural history specimens near Fort Macon and published notes on them, eighteen species mainly of the larger mammals being observed.

4. In 1897 Mr. R. T. Young collected small mammals in Currituck and Perquimans counties. The results of his collecting were published by Mr. S. N. Rhoads.

5. Collection from Roan Mt. in 1897 made by Mr. S. N. Rhoads.

6. Collections from Roan Mt. in 1887, 1892, 1893 and 1894 made by and for the United States Biological Survey.

7. Skulls and skins of a number of furbearing mammals trapped by Mr. Walton E. Stone from 1897 to 1900 in the neighborhood of Rosebay, Hyde county.

8. From about 1888 to 1900 my brother and myself collected small mammals near Raleigh, in Wake county, a list of which was published in the *American Naturalist*, May 1897.

9. Specimens received by the State Museum at Raleigh from various parts of the State. These have been mainly of the larger species.

II. RECORDS OF NORTH CAROLINA MAMMALS.

Records of North Carolina mammals scattered through the papers of American Mammalogists. (A list of all papers consulted by the author will be found at the end of the catalogue.)

III. LISTS OF THE LARGER AND BETTER KNOWN MAMMALS.

Lists of the larger and better known mammals of their vicinity received from Messrs. J. H. Armfield, Guilford county;

R. W. Collett, Cherokee county; R. D. Foxhall, Edgecombe county; N. W. Fain, Buncombe county; K. E. Shore, Forsyth county; T. A. Smithwick, Bertie county; Dr. J. W. P. Smithwick, Lenoir county; Miss Maggie Wicker, Moore county; and Dr. Donald Wilson, Cherokee county, to all of whom I am very much indebted for the information furnished.

Thanks are also due to Messrs. H. H. Brimley, Curator State Museum, Raleigh, N. C.; Dr. Witmer Stone, Academy of Natural Sciences, Philadelphia; G. S. Miller, Jr., United States National Museum; S. N. Rhoads, Philadelphia; Dr. J. A. Allen, American Museum of Natural History, New York; Outram Bangs, Boston, Mass.; and especially to Dr. C. Hart Merriam, Chief of the United States Biological Survey, for information given and assistance rendered.

The class Mammalia comprises warm blooded vertebrates, usually clothed with hair and never with feathers. A number of other characteristics define the class, but the warm blood distinguishes it from all other classes of animals except the birds and these are distinguished from mammals by the presence of feathers.

In the following catalogue the orders and families are arranged in the same sequence as in *Jordan's Manual.

Sixty-six species and subspecies are credited herein to North Carolina, and are numbered serially from 1 to 66. Nine other species, not yet known to occur are added in brackets without numbers, in their proper places. Some of the forms included may be really the same as other allied forms also included, or but slightly different, but I have tried to use as good judgment as was possible in the matter.

KEY TO THE ORDERS OF LAND MAMMALS OCCURRING IN NORTH CAROLINA.

a. Female generally (always in our species) provided with a pouch in which the young are carried for a time

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*Manual of the Vertebrates of the Northern United States, by D. S. Jordan, Chicago, 1899, A. C. McClurg & Co.

after birth. Order I. Marsupialia. (Opossums, etc.)

aa. Females without external pouch for carrying the young.

b. Fore limbs modified to serve as wings. Order II. Cheiroptera (Bats).

bb. Fore limbs not modified to serve as wings.

c. Toes provided with hoofs. Order III. Ungulata. (Deer, Cattle, etc.)

cc. Toes not furnished with hoofs, but with claws of some sort.

d. Front teeth chisel shaped and separated from jaw teeth by a wide space. Order IV. Glires. (Squirrels, Rats, Mice, Rabbits, etc.)

dd. Front teeth not chisel shaped, tooth row nearly or quite continuous.

e. Brain large, well developed. In our species size large, eyes well developed, muzzle not greatly elongated. Order V. Ferae. (The flesh eaters, Cats, Dogs, Foxes, Bears, etc.)

ee. Brain small, not highly developed. In our species size small, eyes small or rudimentary, muzzle elongate. Order VI. Insectivora. (Moles and Shrews.)

ORDER I. MARSUPIALIA.

FAMILY DIDELPHIDAE (THE OPOSSUMS).

The members of this family, which is the only one represented in America, have 50 teeth, a prehensile tail, and the hind feet with five toes each, the outer one of which is clawless and thumb-like. Our only genus is,

GENUS DIDELPHIS, L.

1. *Didelphis virginiana*, Kerr. Common Opossum. Blackish

varied with grayish white, ears naked, leathery. *L. 28. T. 11. The Opossum is found throughout the whole State even in the most thickly settled portions.

ORDER II. GLIRES.

(THE RODENTS OR GNAWERS.)

Front teeth long, chisel-shaped; cheek teeth broad, short, flat-crowned, a wide toothless space between the front teeth and cheek teeth.

Five of the American families of this group are found in North Carolina, and may be distinguished as follows:

FAMILIES OF GLIRES.

a. Upper front teeth four, the second pair small and placed directly behind the first pair. Family Leporidae. (Hares and Rabbits.)

aa. Upper front teeth two.
  b. Tail very broad, flattened from above downwards. Family Castoridae. (Beavers.)
  bb. Tail round or flattened from side to side.
    c. At least four well developed grinding teeth on each side in each jaw. Tail bushy. Family Sciuridae. (Squirrels.)
    cc. Never more than three well developed grinding teeth in each jaw, tail close haired or nearly naked.
      d. Hind feet not greatly elongated. Family Muridae. (Rats and Mice.)
      dd. Hind feet and tail greatly elongated. Family Dipodidae. (Jumping Mice.)

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*L=total length of animal from tip of nose to end of tail bone (not to end of hairs on end of tail).

T=length of tail from root to end of vertebrae (not to end of hairs). Measurements are in inches.

FAMILY LEPORIDAE. (THE RABBITS.)

Upper front teeth four, the second pair small and placed directly behind the others, which are grooved in front, teeth 28 in all. Tail short, recurved, eyes large, ears long, soles furred. The family includes the single genus Lepus, two species of which are found in North Carolina.

GENUS LEPUS, L.

a. *Post orbital process fused with the skull* (*subgenus Limnilagus*).

2. *L. palustris*, Bachm. Marsh Rabbit. Yellowish brown: tail very short, ashy not white, below. L. 17. T. 1. Ear 2½. Found in the marshes of the eastern part of the State, extending as far north as Hyde county and as far east as Lenoir county.

aa. *Post orbital processes not fused with the skull, but touching it behind enclosing a foramen* (*subgenus Sylvilagus.*)

3. *L. floridanus mallurus* Thomas. Cottontail Rabbit. Much grayer than the preceding, the tail twice as long, cottony white below. L. 18. T. 2. Ear 2⅓, hind foot 3¾. Common throughout the whole State.

(The Southern Varying Hare, *Lepus americanus virginianus* Harlan, a member of a third subgenus Lepus, which has the post orbital processes free behind, occurs in the Alleghanies as far south as Virginia. This is rusty brown above, the tail dull yellowish or whitish below. L. 19. T. 2. Ear 3. Hind foot 5½.)

FAMILY DIPODIDAE (JERBOAS AND JUMPING MICE).

Front teeth two in each jaw, in our species grooved in front, cheek teeth usually four on each side in upper jaw (three in one species). There is only one American genus, two species of which occur in the State.

GENUS ZAPUS, COUES.

a. *A small, probably useless, tooth in front of first well developed grinder in upper jaw. Teeth 18 in number. Tail in our species brown to the extreme tip* (*subgenus Zapus*).

4. *Z. hudsonius americanus* Barton. Southern Jumping Mouse. Back dusky brown faintly tinged with reddish buff, sides reddish buff very slightly grizzled; under parts white tinged with yellowish. L. 7½. T. 4½. Hind foot 1⅛. Only known in this State from Wake county (Raleigh), the most southern locality it has been recorded from.

5. *Z. hudsonius hudsonius* Zimmermann. Northern Jumping Mouse. Back yellowish brown; sides light grayish buff, slightly sprinkled with black, belly white tinged with yellowish. L. 8½. T. 5⅛. Hind foot 1 3-16. Known only in this State from Roan Mt., the most southern locality from which it is known.

aa. *No small tooth in front of first well developed grinder in upper jaw, teeth 16; tail more or less tipped with white* (*subgenus Napaezapus*).

6. *Z. insignis roanensis* Preble. Roan Mt. Jumping Mouse. Sides bright tawny ochraceous; back much darker. Under parts pure white. Tail more or less tipped with white. L. 8¾. T. 5⅛. Hind foot 1 3-16. Known only from the evergreen forests of Roan Mt.

FAMILY MURIDAE.

Front teeth two, cheek teeth never more than three in each jaw. In the species that occur within our limits the hind feet and legs are never greatly elongated for jumping. Ten of the numerous genera occur in the State, one genus with its three or four species being an introduction from the old world, the remaining nine genera are all natives.

a. Grinding teeth with tubercles arranged in three transverse rows, very distinct in teeth of upper jaw (subfam. Murinae, Old World Rats and Mice). GENUS MUS, aa. Grinding teeth with tubercles in two rows or without distinct tubercles of any kind.

b. Crowns of grinding teeth with tubercles in two rows.

bb. Crowns of grinding teeth divided into loops or triangles, (subfam. Cricetinae, American Rats and Mice).

c. Upper front teeth grooved, size small.
GENUS REITHRODONTOMYS.

cc. Upper front teeth not grooved.

d. Tail as long as or longer than head and body, total length of adults 9 inches or over, fur coarse.
GENUS ORYZOMYS.

dd. Tail much shorter than head and body, total length of adults 9½ inches or over, form stout, fur coarse.
GENUS SIGMODON.

ddd. Total length of adults under 8 inches, fur fine and soft, belly white. Tail as long as head and body or somewhat shorter.
GENUS PEROMYSCUS.

e. Upper front teeth narrow, compressed; tail always eyes and ears large, belly white, (subfam. Neotominae, Wood Rats and Cave Rats).
GENUS NEOTOMA.

ee. Upper front teeth broad; tail usually short; ears and eyes small; belly generally not white (subfam. Microtinae, Voles and Lemmings).

f. Lower front teeth short, their roots terminating on inner side of grinders (upper front teeth grooved in our species).
GENUS SYNAPTOMYS.

ff. Lower front teeth long, their roots extending under posterior grinding teeth into outer side of jaw.

g. Tail flattened sideways, size large.
GENUS FIBER.

gg. Tail round, size small or medium.

h. Grinding teeth without roots (prongs).
GENUS MICROTUS.

hh. Grinding teeth with roots (prongs) in adults.
GENUS EVOTOMYS.

GENUS MUS, L. (Introduced Rats and Mice).

7. *Mus musculus* L. House Mouse. Brownish gray, paler below. L. 6¾. T. 3⅜. Very common in houses and largely so in fields also.

8. *M. alexandrinus* Geoff, St. Hil. Roof Rat. Brown, under parts white. Tail as long or longer than head and body; about size of *Mus rattus.* Common at Raleigh and probably the common house rat of the whole State.

(*M. rattus* L. Black Rat. Blue black darker on the back, more slaty on the belly. L. 15¾. T. 8½. Tail as in the Roof Rat about as long as head and body. The Black Rat was formerly wide spread in the eastern United States, but has been in the north almost exterminated by the Brown Rat. It very probably occurs or has occurred in the past, but we have no records.)

9. *M. norvegicus* Erxl. Brown Rat, Wharf Rat. Brownish above, grayish below, tail shorter than head and body. L. 15¾. T. 7⅛. The common house rat of the north as *M. alexandrinus* is of the south, but the only record we have for North Carolina is that of Coues, who says they were common in the vicinity of Fort Macon in 1870.

GENUS SIGMODON (Cotton Rats).

10. *S. hispidus* Say & Ord. Cotton Rat. Upper parts brown coarsely and irregularly varied with brownish black, brownish white below. Form short and stout. L. 10½. T. 4. Only recorded in this State from Raleigh, where it is abundant, but undoubtedly occurs commonly throughout the greater part of eastern North Carolina.

GENUS REITHRODONTOMYS, GIGLIOLI (Harvest Mice).

11. *Reithrodontomys lecontei lecontei* Aud & Bach. Harvest Mouse. Light brown above, whitish beneath. L. 5. T. 2⅜. Much like a House Mouse but smaller and distinguished by its grooved front teeth and furry ears. Has only been taken

in Wake and Bertie counties, where it is common, but doubtless occurs throughout the greater part of the State.

(*Reithrodontomys lecontei impiger* Bangs. Virginia Harvest Mouse. Russet brown above, dull white below. L. 4½. T. 2. Common at White Sulphur Springs, West Virginia, and therefore probably occurs in the northeastern part of the State but seems scarcely distinct from the preceding.)

GENUS PEROMYSCUS, GLOGER (Deer Mice).

12. *P. leucopus* Raf. Deer Mouse. Tail 40 to 45 per cent. of total length. Chestnut brown above, pure white below sharply defined against the color of the sides, tail bicolor. Young bluish gray. L. 6½. T. 3. Hind foot 1 3-16. Common in Wake, Bertie, Buncombe, Perquimans and Currituck counties, and probably throughout the whole State.

13. *P. canadensis nubiterrae* Rhoads. Cloudland Deer Mouse. Dull brownish above, white below, the two colors sharply defined: tail as long as head and body with a tuft of hairs at tip. L. 6½. T. 3½. Only known from Roan Mt. in Mitchell county.

14. *P. gossypinus* Leconte. Cotton Mouse. Dark brown above with broad darker dorsal band, under parts gray, feet and hands grayish white. Young blackish slate gray above, slate gray beneath. L. 7. T. 2⅞. This species replaces its smaller relative (*P. leucopus*) in the southeastern United States and in this State most probably occurs throughout the whole southeastern portion but is so far only known to occur in Bertie and Currituck counties.

15. *P. nuttali* Harlan. Golden Mouse. Golden cinnamon above, yellowish white beneath passing gradually on the sides into the color of the back. Tail unicolor. Young similar to the adults in color. L. 6. T. 2½. An arboreal species building its nest 6 to 12 feet high in reeds or bushes in lowland thickets. Probably common throughout most of the State, as it has been taken in Bertie, Wake, Halifax, Perquimans, and Buncombe counties.

GENUS ORYZOMYS, BAIRD (Marsh Rats).

16. *O. palustris* Harlan. Ricefield Rat. Dark brown above, whitish below, ears short, furry, tail about as long as head and body, hind feet large. L. 9½. T. 4¾. A semi-aquatic species inhabiting cattail swamps and marshes from Florida to New Jersey. In this State it has only been taken in Wake county (Raleigh), where it is not uncommon in suitable situations.

GENUS NEOTOMA, SAY & ORD (Wood Rats.)

17. *N. pennsylvanica* Stone. Alleghany Cave Rat. Grayish above, white below. Tail sharply bicolor. L. 16¼. T. 7⅜. Common in caves and rocky woods throughout the Alleghanies. Only known in this State from Roan Mt., Mitchell county.

(*N. floridiana* Ord. Wood Rat. Brownish gray above, the sides more yellowish, white below, tail furry, bicolor. L. 16. T. 7½. I have had nests described to me by colored men, who said they had seen them many years ago in the eastern part of the State, which might have belonged to this species. So far as I know, however, it is not known to occur nearer here than southern Georgia.)

GENUS SYNAPTOMYS, BAIRD.

18. *S. cooperi* Baird. Cooper's Lemming. Color grizzled gray and yellowish brown above, thickly sprinkled with black; dirty white below. L. 4⅞. T. ¾. Only known in this State from Roan Mt., Mitchell county, and Chapanoke, Perquimans county. Inhabits sphagnum bogs.

GENUS FIBER, CUVIER (Muskrats).

19. *F. zibethicus* L. Muskrat. Color brown, much suffused with yellowish and reddish (or black above and below, or black above and paler below than in the common form). L. 24. T. 10½. Common along streams throughout the State.

The black form with pale belly is not uncommon at Raleigh, and we have also had it from Hyde county. The all black form we have only seen from Hyde county.

20. *F. macrodon*, Merriam. Dismal Swamp Muskrat. "Color very much darker and teeth very much larger, otherwise as in *F. zibethicus*" (Jordan's Manual) described from Dismal Swamp, Virginia, but undoubtedly has no respect for State lines.

GENUS MICROTUS, SCHRANK (Meadow Mice or Voles).

21. *M. pennsylvanicus pennsylvanicus* Ord. Meadow Mice. Upper parts dark brown, much sprinkled with black, under parts gray. L. 6¾. T. 2. Common at Raleigh and in Mitchell and Buncombe counties. The common mouse of wet meadows, but occurring sparingly on the uplands. Not known south of North Carolina, except in the mountains.

22. *M. pennsylvanicus nigrans* Rhoads. Albemarle Meadow Mouse. Above dark brownish slate black, dark brown on sides, under parts dark brown. L. 7. T. 2. Only known from Currituck, Currituck county, the type locality.

23. *M. pinetorum pinetorum* LeConte. Pine Mouse. Fur dense velvety and mole like, eyes and ears very small, claws on forefeet longest. Color above chestnut, ashy below, young slaty. L. 5. T. ⅞. Common at Raleigh and in Bertie and Currituck counties, and probably throughout the State. This species digs burrows of its own or follows the mole runs under ground, feeding on such crops as peanuts, sweet potatoes and Irish potatoes without the damage being evident till the crop is dug.

24. *M. pinetorum scalopsoides* Aud & Bach. Northern Pine Mouse. Adults reddish brown, lighter than in *pinetorum*. One specimen from Magnetic City, Mitchell county, and two from Currituck referred to this form by Bailey (*N. A. Fauna, No. 17, 1900*).

GENUS EVOTOMYS, COUES.

25. *E. carolinensis* Merriam. Carolina Redbacked Mouse.

Ears large, projecting conspicuously above the fur, back dark chestnut fading insensibly into the brown of the sides. L. 5⅞. T. 1¾. Probably found on the higher summits of the mountainous region of the State, but so far recorded only from Macon and Mitchell counties.

FAMILY CASTORIDAE (THE BEAVERS).

Large, clumsily built, aquatic rodents with four broad, rootless cheek teeth in each side of each jaw. Tail very broad and scaly, flattened from above, downward.

GENUS CASTOR, L.

26. *C. canadensis carolinensis* Rhoads. Carolinian Beaver. Scaly portion of tail less than twice as long as wide, fur relatively short and harsh. L. 35. In this State the beaver occurs sparingly on the Dan River in Stokes county (the type locality of the subspecies) and is also reported from Bertie county. A specimen taken some fifteen or twenty years ago at Weldon is in the State Museum at Raleigh. These localities are all on the Roanoke River or its tributaries. Mr. J. H. Armfield reports a few occurring in Beaver Swamp in the northern part of Guilford county and southern part of Rockingham, and Mr. K. E. Shore reports them from the Yadkin River, between Yadkin and Forsyth counties.

FAMILY SCIURIDAE (THE SQUIRRELS).

Upper front teeth two; upper cheek teeth four or five on each side; lower cheek teeth four on each side. A well developed bony process on skull above and behind eye socket (postorbital process); tail round covered with long hairs which are usually so arranged as to form a broad flat brush. Four of the North American genera occur in the State.

a. Sides with a densely furred membrane joining front and hind legs (Flying Squirrels)....GENUS SCIUROPTERUS.
aa. Sides without membrane.

b. Form stout and clumsy; tail less than half as long as body; skull nearly flat on top (Woodchucks).
GENUS ARCTOMYS.

bb. Form slender and graceful; tail much more than half as long as body; top of skull distinctly rounded.

c. Cheek pouches present; back striped (Chipmunks).
GENUS TAMIAS.

cc. Cheek pouches absent; back not striped (Squirrels).
GENUS SCIURUS.

GENUS SCIURUS, L. (Squirrels).

27. *S. hudsonius loquax* Bangs. Southern Red Squirrel, Mountain Boomer. Back red, under parts white, edge of tail yellowish. L. 12½. T. 5⅝. (The length of tail does not include the distance the hairs project beyond the flesh but is the length of the tail vertebrae only. This is important to note in the case of the Squirrels and other mammals with hairy tails.) The Mountain Boomer is found throughout the mountains of the State from Cherokee to the Virginia line.

28. *S. carolinensis* Gmelin. Southern Gray Squirrel. Size medium, back dark yellowish rusty-gray. L. 18. T. 8. Common throughout the whole State.

29. *S. niger* L. Southern Fox Squirrel. Largest of the eastern Squirrels. Color very variable, gray, rusty or black, but the ears and nose are always white. Feet and hands very large, fur coarse and harsh. L. 25. T. 12. Said by Bangs to be wholly confined to the great pine forest of the South Atlantic and Gulf States. Only known in this State from Tarboro and Craven county. Specimens from the latter county are in the State Museum.

(*S. ludovicianus* Gray. Northern Fox Squirrel. Back mixed black and rusty, belly varying from pale rust color to rusty white; ears rusty (never white but the nose is sometimes white). L. 23. T. 10½. Fox Squirrels are recorded from the neighborhood of Asheville by Mr. N. W. Fain, and from Cherokee county by Dr. Donald Wilson and may be this species or the preceding. Dr. Wilson sent me a skin without the skull from his county which I sent to Mr. Outram Bangs for determination, and he wrote me as follows: "About the squirrel I am puzzled. If I had the skull I could be sure. It looks to me, however, like *neglectus* rather than *niger*. There is a great difference in size between them, and this skin seems small, but of course I cannot tell how old it is. The color is variable in both species, but as you say, the ears in your skin are not white enough. Although a very unsatisfactory identification, I think I should call it *Sciurus ludovicianus neglectus*. I should hate, however, to publish this as positive proof one way or the other, without seeing the skull."

GENUS TAMIAS, ILLIGER (Chipmunks).

30. *T. striatus* L. Chipmunk. Reddish brown, back with five black stripes and two whitish ones. L. 11. T. 4½. The Chipmunk is found throughout the western half of the State extending as far east as the western edge of Raleigh township, in Wake county, and as far south as Cherokee in the mountains.

GENUS ARCTOMYS, SCHREBER (Woodchucks).

31. *A. monax* L. Woodchuck, Ground Hog. Grizzly gray, varied with chestnut, yellowish and blackish; under parts reddish. L. 18. T. 4½. Common throughout the mountainous region of the State.

GENUS SCIUROPTERUS, F. CUVIER (Flying Squirrels).

32. *S. volans* L. Flying Squirrel. Back drab, somewhat shaded with russet, belly pure white to extreme base of hairs. L. 9. T. 4. Common throughout the whole State.

ORDER III. INSECTIVORA.

Canine teeth present, but usually not conspicuously developed; cheek teeth formed for chopping; toes provided with claws; brain small. (Our species are all small, under 8 inches in length, eyes and ears small or rudimentary, fur more or less molelike.)

Two families occur in North America and another in the West Indies, while no members of this group are known from South America except the extreme northwest corner only.

a. Forefeet highly modified for digging; external ear absent (Moles) FAMILY TALPIDAE.
aa. Forefeet not highly modified for digging; external ear present (Shrews) FAMILY SORICIDAE.

FAMILY TALPIDAE (THE MOLES).

Body thick and clumsy without distinct neck; eyes rudimentary or concealed; no external ear; front feet very large, the nearly circular palm held lengthwise; fur very soft and velvety.

a. Tip of muzzle with a fringe of fleshy projections; tail long; teeth 44. GENUS CONDYLURA.
aa. Tip of muzzle without a fringe of fleshy projections; tail short.
  b. Teeth 36; tail slender and nearly naked. GENUS SCALOPS.
  bb. Teeth 44; tail thick and very hairy. GENUS PARASCALOPS.

GENUS CONDYLURA, ILLIGER.

33. *C. cristata* L. Starnosed Mole. Dusky brown, paler and grayer below; tail nearly as long as head and body. L. 6¾. T. 2⅞. Known only in this State from Mitchell county, where it was taken at Magnetic City by the collectors of the Biological Survey of the United States Department of Agriculture in 1892 or 1893, and from Buncombe county, where a single specimen was taken by Mrs. J. S. Cairns, at Weaverville, February 6, 1896. It is said to inhabit wet places.

GENUS PARASCALOPS, TRUE.

34. *P. breweri* Bachm. Brewer's Mole. Dark lead gray,

seldom, if ever, tinged with rusty. Tail dark. L. 5 13-16. T. 1 3-16. Like the preceding, a northern species extending its range southward in the mountains. Said to inhabit dry soil. Known only in this State by the numerous specimens taken by the collectors of the United States Biological Survey in 1892 and 1893 at Magnetic City, in Mitchell county.

GENUS SCALOPS, ILLIGER.

35. *S. aquaticus* L. Common Mole. Light glossy slate brown, tinged with rusty; tail whitish. L. 6⅜. T. 1 1-16. The Common Mole is abundant throughout the State.

FAMILY SORICIDAE (THE SHREWS).

Body usually slender and mouse like with a distinct neck, eyes well developed but very small, a distinct external ear, front feet small, not mole like. Shrews are small animals, something like mice, but with pointed snouts and small eyes, the Mole Shrews of the genus Blarina have, however, a casual resemblance to little moles, except in the forefeet. Two genera occur in North Carolina.

a. Ears completely hidden by the fur, tail short. GENUS BLARINA.
aa. Ears distinctly visible, tail long. GENUS SOREX.

GENUS BLARINA GRAY.

a. *Teeth 32, total length 4 inches or over (subgenus Blarina).*

36. *B. brevicauda* Say. Mole Shrew. Color sooty slate brown above, more ashy below. L. 4¾. T. 1. Found throughout the mountains of the State from Cherokee to the Virginia line.

37. *B. carolinensis* Bachm. Carolina Shrew. Very similar to the preceding, but smaller and more slender, being only about 4 inches in total length. Occurs probably throughout the State except in the mountains, but has only been taken in Wake (Raleigh, Apex) and Perquimans counties (Chapanoke).

38. *B. telmalestes* Merr. Dismal Swamp Mole Shrew. About same size as *brevicauda*, but more plumbeous in color, and with a narrower skull. Taken by Dr. Merriam at Dismal Swamp, Virginia, and by Mr. R. T. Young, at Chapanoke, Perquimans county, and Currituck, Currituck county. The relationship of this and the two preceding forms to one another does not seem clear to me and hence I list them as full species "without prejudice."

aa. Teeth 30, in our species length about 3 inches.

39. *B. parva* Say. Little Mole Shrew. Color brownish above, ashy below. L. 3. T. 9-16. Its range in the State is probably about that of *B. carolinensis*, but it is at present only recorded from Wake and Bertie counties.

GENUS SOREX, L.

(a. *Total length over 5½ inches; hind feet conspicuously fringed subgenus Neosorex*). *S. albibarbis* Cope. Eastern Marsh Shrew. Upper parts blackish slate with a slight hoary cast; chin and throat grayish white, rest lower parts of dusky. L. 6⅛. T. 2¾. The Marsh Shrew inhabits marshes and the borders of streams, south in the mountains to Pennsylvania and probably further.)

aa. *Total length under 5 inches, hind feet not fringed* (sub*genus Sorex*).

40. *S. fumeus* Miller. Smoky Shrew. Smoky slate color, slightly paler below. L. 4⅛. T. 1¾.

41. *S. personatus* Geoff St. Hil. Masked Shrew. Upper parts dark brown, under parts whitish gray. L. 4⅛. T. 1 9-16. This and the preceding have both been taken by the collectors of the United States Biological Survey on Roan Mt., Mitchell county, in 1892.

42. *S. longirostris* Bach. Southern Shrew. Smallest of the eastern shrews. Chestnut brown above, ashy tinged with drab below. L. 3⅜. T. 1¼. Rare at Raleigh and one specimen known from Bertie county. The limits of the range

of this species are unknown, the above specimens being the only ones known to have been taken anywhere, since the species was described by Bachman from specimens taken in the swamps of the Santee River, South Carolina.

43. *S. fisheri*, Merr. Dismal Swamp Shrew. Similar to the preceding, but larger and coloration duller. L. 4⅛. T. 1½. This and the preceding have the third unicuspid tooth decidedly smaller than the fourth, whereas in *S. fumeus* and *S. personatus* the reverse is the case. Described by Dr. Merriam from Dismal Swamp, Virginia, and taken by Mr. R. T. Young at Chapanoke, Perquimans county.

ORDER IV. CHEIROPTERA. (BATS.)

Forelimbs greatly developed, the elongated fingers supporting a membrane by means of which true flight is performed.

a. Tail included in the flying membrane nearly or quite to tip, nose without leaf-like fleshy growths.
FAMILY VESPERTILIONIDAE.

aa. Tail in our species free from the membrane for its apical half. FAMILY EMBALLONURIDAE.
(One species of the Emballonuridae, *Nyctinomus cynocephalus* Lec. The Florida House Bat, a small brown bat with tail projecting for about half its length beyond the membrane and with naked wings is common in Florida and the Gulf States and may possibly occasionally straggle as far north as this State.)

FAMILY VESPERTILIONDAE. (The Typical Bats.)

a. Nostrils simple, at tip of snout; ears moderate; forehead not grooved.

b. Upper front teeth four, membrane between legs not completely furred above.

c. Fur blackish, frosted with white.
GENUS LASIONYCTERIS.
cc. Fur not blackish, not frosted with white.
d. Total length over four inches, teeth 32.
GENUS VESPERTILIO.
dd. Total length under four inches.
e. Color dull brown; ears rather long; teeth 38.
GENUS MYOTIS.
ee. Color light yellowish brown, teeth 34.
GENUS PIPISTRELLUS.
bb. Upper front teeth two.
f. Membrane between hind legs completely furred above, ears short and round. GENUS LASIURUS.
ff. Membrane between hind legs not furred above.
GENUS NYCTICEIUS.

aa. Nostril margined behind by grooves; cheeks with large excrescences; ears very large, an inch high.
GENUS CORINORHINUS.

GENUS LASIURUS, GRAY.

44. *L. cineureus* Beauv. Hoary Bat. General color a mixture of light yellowish brown, deep umber brown, and white. L. 5½. T. 2. Spread of wing 14. Has been taken by Cairns in Buncombe county, and the Smithwicks in Bertie county and Coues records it as occasional in summer at Fort Macon.

45. *L. borealis* Muller. Red Bat. General color varying from rufus red to yellowish gray, a white spot at shoulder, sometimes connected with its fellow by a white chest band. L. 4¼. T. 2. Spread 12. Common in Wake, Bertie, Buncombe, and at Fort Macon, also at Magnetic City, and on Roan Mt., and probably throughout the State.

GENUS NYCTICEIUS, RAF.

46. *N. humeralis* Raf. Twilight Bat. Dull umber brown

above, paler below. Common in Bertie, Wake and Buncombe, and probably throughout the State. L. 3½. Spread 9.

GENUS MYOTIS, KAUP.

47. *M. subulatus* Say. Say's Bat. Dull brown, slightly paler and more yellowish below. Ear when laid forward reaching considerably beyond nose. L. 3⅜. Spread 9. A single specimen taken at Raleigh September 13, 1902, is referred by me to this species as it agrees with the foregoing characters.

48. *M. lucifugus* Lec. Little Brown Bat. Ear when laid forward barely reaching nostril, size and color as in *M. subulatus.* Mr. G. S. Miller, Jr., mentions a specimen from Mitchell county, and has identified a specimen from Buncombe county, kindly loaned me by Mr. W. E. Snyder, as this species, and Dr. Witmer Stone refers to it a specimen from Bertie county. Besides these, I have seen 6 from Buncombe, 2 from Bertie county, and 2 from Raleigh, which were either this or the preceding, but at the time we had them, the two species were confused, and I have been unable to locate the specimens and have them correctly placed.

GENUS LASIONYCTERIS, PETERS.

49. *L. noctivagans* Lec. Silver Black Bat. Blackish, frosted with white, membrane between hind legs furred to about the middle above. L. 4. Spread of wing 12. This bat apparently occurs all over the State, but does not seem to be common in any locality. Six specimens are recorded from Bertie county, a dozen or more from Wake, one from Buncombe, and one from Mitchell.

GENUS PIPISTRELLUS, KAUP.

50. *P. subflavus* F. Cuvier. Georgia Bat. General color light yellowish brown. L. 3⅜. Spread 9. This is the smallest of our bats and is common in Bertie, Buncombe and Wake, and probably throughout the State.

GENUS VESPERTILIO, L.

51. *V. fuscus* Beauv. Big Brown Bat. Brown, paler below. 4⅝. Spread 12. This species is known from Bertie, Wake and Buncombe, but is not common in either county.

GENUS CORINORHINUS, H. ALLEN.

52. *C. macrotis* Lec. Big Eared Bat. Blackish, fur soft and long. L. 3½. Spread 11. One taken by Cairns at Weaverville, Buncombe county, April 7, 1895, and three by the Smithwicks in Bertie county, February 1, 1893, and October 24, 1894, (two specimens) are the only records we have of this southern species. (Since the above was written the State Museum has received a specimen from Goldsboro.)

ORDER V. UNGULATA.

(THE HOOFED ANIMALS.)

Herbivorous mammals provided with one to four enlarged and thickened hoofs on each foot. The order contains mainly large species and includes such domestic animals as the horse, cow, hog, sheep, goat, etc.

Only one of the two groups of Ungulata, the Artiodactyla or even toed Ungulates, is represented in our fauna, and only two families of that.

Families of Ungulata now or formerly occurring in the State:

a. Horns solid, usually branching, present in our species only in the male (The Deer). FAMILY CERVIDAE.

aa. Horns permanent, hollow, each enclosing a bony core or process of the skull (The Cattle). FAMILY BOVIDAE.

FAMILY CERVIDAE (THE DEER).

Horns solid, shed every year; wanting in the female except in the Reindeer. Only one species occurs in the State, but another doubtless did in earlier days.

a. Horns large, curved mostly backward, the tines all directed forwards, size large. GENUS CERVUS.

aa. Horns small, curved forward, the tines all directed upwards, size smaller. GENUS ODOCOILEUS.

GENUS CERVUS, L.

(*C. canadensis* Erxl. Eastern Wapiti, American Elk. Reddish brown, paler in winter; height at shoulders five feet; horns five feet long. Now extinct in the United States, but probably occurred in the western part of the State 150 years ago.)

GENUS ODOCOILEUS, RAF.

53. *O. virgianus* Bodd. Virginia Deer. Color in summer reddish, grayer in winter, under parts white. Not uncommon in the eastern section of the State and in the mountains, but rare or absent in the more thickly settled portions of the center.

FAMILY BOVIDAE. (THE CATTLE AND ANTELOPES.)

Only one genus, Bison, ever occurred east of the Mississippi, the cow, goat and sheep belong to this family.

GENUS BISON, H. SMITH.

(*B. bison* L. American Bison, Buffalo. The Buffalo was no doubt found in the western part of the State in early days.)

ORDER VI. FERAE.

(THE CARNIVORA OR FLESH EATERS.)

Canine teeth well developed, cheek teeth formed for cutting, front teeth small in a row between the canines. Toes provided with claws. Brain large, well developed.

a. Limbs modified for swimming and useless for walking, hind feet not capable of being turned forward (The True Seals). FAMILY PHOCIDAE.
aa. Limbs fitted for walking.
  b. Hind feet with 4 toes.
    c. Claws capable of being withdrawn into a sheath, muzzle broad and short, teeth not more than 30 (The Cats). FAMILY FELIDAE.
    cc. Claws blunt, not retractile, teeth 42 (Dogs, Wolves and Foxes). FAMILY CANIDAE.
  bb. Hind feet with five toes.
    d. Entire sole applied to the ground in walking.
      e. Size large, tail rudimentary (The Bears). FAMILY URSIDAE.
      ee. Size medium, tail well developed (Raccoons). FAMILY PROCYONIDAE.
    dd. Entire sole not applied to the ground in walking (Weasels, Minks, Otters, Skunks, etc.). FAMILY MUSTELIDAE.

FAMILY PHOCIDAE. (THE SEALS.)

Only one genus and species occur on the coast.

GENUS PHOCA, L.

54. *P. vitulina* L. Harbor Seal. Grayish or brownish. L. five feet, female smaller. Occasional on our coast. A female in the State Museum from Craven county.

FAMILY PROCYONIDAE.

Plantigrade carnivora of small size with comparatively slender body and well developed tail. Teeth 40. Only one genus and species occur in the eastern United States.

GENUS PROCYON, STORR.

55. *P. lotor* L. Raccoon, Coon. Grayish, hairs black tipped with black rings, a black cheek patch. L. 33. T. 10½. The Raccoon is still found throughout the State, but is quite rare in the more thickly settled districts.

FAMILY URSIDAE (THE BEARS).

Plantigrade carnivora of large size, with rudimentary tail. Only one genus and species is known from the State.

GENUS URSUS, L.

56. *U. americanus* Pallas. Common American Bear, Hog Bear. Color blackish or brownish, variable. Still not uncommon in the swamps of the eastern and mountains of the western parts of the State, but not now found in the central portion.

FAMILY MUSTELIDAE (THE WEASELS).

Carnivora with the feet either plantigrade or digitigrade, the toes five on all four feet. Most species are provided with glands near the anus which secrete a bad smelling liquid. Teeth 32 to 38. Our species are usually of small or medium size.

a. Toes conspicuously webbed, snout short, high and blunt, teeth 36 (Otters). GENUS LUTRA.
aa. Toes not much webbed, snout longer, teeth 34.
  b. Tail closely furred, claws short (Minks and Weasels). GENUS PUTORIUS.
  bb. Tail bushy, claws long (Skunks).
    c. Form stout and heavy. GENUS MEPHITIS.
    cc. Form slender. GENUS SPILOGALE.

GENUS LUTRA, BRISSON.

57. *L. hudsonica* Desm. American Otter. L. 3½ feet. T. 16 inches. Color liver brown. Our form is *L. h. lataxina*

(F. Cuvier), with colors lighter than in the Northern Otter. The Otter is found throughout the State, but is apparently rarest in the mountains and most plentiful in the east.

GENUS PUTORIUS, CUVIER.

58. *P. vison lutreocephalus* Harlan. Carolina Mink. Color dark chestnut brown. L. 27. T. 8¼. The Mink is found commonly throughout the State, it being a semi-aquatic animal living mainly along watercourses.

59. *P. noveboracensis notius* Bangs. Southern Weasel. Brown above, yellowish white below, tail brown, black for posterior half. L. 16. T. 5½, the female much smaller, L. 12¾, T. 4¼. Rare in Wake (only two specimens seen in twenty years) and in Bertie, but rather common in Buncombe and Mitchell counties, and probably in the mountains generally. No Weasels are known in the eastern United States from south of Raleigh until we reach Florida.

GENUS MEPHITIS, CUVIER.

60. *M. elongata* Bangs. Large Southern Skunk. Polecat. Color black, a patch on the back of the head and two stripes extending back from it white. These stripes may be so greatly enlarged that the animal is nearly all white, or so greatly reduced that it is nearly all black. Tail very bushy with a white tip, the white on tail as variable in amount as that on body. L. 24. T. 9. Occurs only in the southern half of the State from the coast to the mountains. Very rare in Wake county, and not found in Bertie, Forsyth, Guilford, or other counties in the northern half of the State. The secretions of the anal glands (not urine, as is commonly supposed,) are so abundant and offensive in all skunks as to be the animal's chief weapon of offense.

GENUS SPILOGALE, GRAY.

61. *S. ringens* Merr. Little Striped Skunk. About the size and shape of a mink, color black with four narrow,

parallel, white stripes down the back, these breaking up on the rump into spots and transverse bars. Tail black with long, white pencil at tip. L. 18½. T. 7½. The Little Striped Skunk is found throughout the mountains where it seems to be commoner than the large skunk.

FAMILY CANIDAE (THE DOGS).

Carnivora that walk on the toes only, never on the sole of the foot; claws blunt; hind toes 4; teeth 42 in our species.

- **a.** Upper front teeth distinctly lobed, pupil of eye circular (Dogs and Wolves). GENUS CANIS.
- **aa.** Upper front teeth not lobed, pupil of eye elongate not circular.
  - **b.** Tail without mane of stiff hairs, and with abundant soft under fur (Red Foxes). GENUS VULPES.
  - **bb.** Tail with a concealed mane of stiff hairs and without soft fur (Gray Foxes). GENUS UROCYON.

GENUS CANIS, L.

62. *C. occidentalis* Rich. American Wolf. Back brownish or blackish mixed with tawny, belly light tawny or dirty whitish. Total length nearly five feet. Found sparingly throughout the mountains. Dr. Donald Wilson reports it from Graham county, Mr. R. W. Collett says it is growing very scarce in Cherokee, Mr. Fain says there are very few in Buncombe. Mr. H. H. Brimley, Curator of the State Museum, informs me it has been taken in recent years in Yancey, Caldwell and Watauga. Dr. Merriam states that in the year of one of his visits to Roan Mt. a den of wolves was discovered there and the young captured alive (in 1887 or 1892).

GENUS VULPES, RICHARDSON.

63. *V. fulvus* Desm. Red Fox. Reddish, feet and ears blackish, tip of tail white. L. 40. The commoner fox in the mountains and thence eastward along the northern border of

the State to Edgecombe (Foxhall). Not found in Bertie (Smithwick), Wake (Brimley), nor Forsyth (Shore).

GENUS UROCYON, BAIRD.

64. *U. cinereo-argenteus* Muller. Gray Fox. Back a coarse grizzle of blackish and white, belly and region about ears tawny. A black line along back of tail. L. 36. The Gray Fox is the common fox of the State except in the mountains where it is less common.

FAMILY FELIDAE (THE CATS).

Carnivora with short round head and retractile claws. Heel never applied to the ground in walking. Teeth 28 or 30.

a. Tail long, teeth 30, ears not tufted.	GENUS FELIS.
aa. Tail short, teeth 28, ears tufted.	GENUS LYNX.

GENUS FELIS, L.

65. *F. cougar* Kerr. American Panther, Puma. Yellowish brown above, middle line of back darker, under parts whitish. L. 8½ feet. T. 3 feet. A specimen killed near Rose Bay, Hyde, county, some years before the war between the States, according to Mr. Walton E. Stone, is the only authentic record from the State.

GENUS LYNX, KERR.

66. *L. ruffus* Gueld. Wild Cat, Bay Lynx. Back yellowish gray tinged with rufous, much spotted and streaked with black, belly whitish spotted with black, a brownish collar on throat. L. 3 feet. T. 7 inches. Found in the wilder parts of the eastern and western portions of the State. Large specimens of this species are frequently called catamounts and supposed to be a different species, but in every case where the State Museum has endeavored to secure a "catamount," it has always proved to be this species and not the Canada Lynx, which does not occur in the State.

LIST OF PAPERS RELATING MORE OR LESS TO NORTH CAROLINA MAMMALS AND CONSULTED BY THE AUTHOR:

Allen, J. A., "Species of the Genus Reithrodontomys," Bull. A. M. N. H., Vol. XII., 1895, pp. 107 *et seq.* (Mentions *R. lecontei* from Raleigh, North Carolina, but gives its distribution erroneously, as "coast region of South Carolina and Georgia".)

Allen, J. A., "Revision of the Chickarees," Bull. Am. Mus. Nat. Hist., Vol. X., 1898, Article XIV. (Mentions *Sciurus hudsonius loquax* from North Carolina.)

Allen, J. A., "Five New North American Mammals," Bull. A. M. N. H., Vol. XII., 1899, page 13. (Mentions *Lepus floridanus mallurus* from Raleigh.)

Bangs, O., "Three New Weasels From North America," Proc. New Eng. Zool. Club, Vol. I., pp. 53-57, June 9, 1899. (Describes as new *Putoricus noveboracensis notius* from Weaverville and Raleigh, North Carolina.)

Bangs, O., "Notes on North American Mammals," Proc. Boston Soc. Nat. Hist. Vol. XXVI., July 31, 1895.

Bangs, O., "The Cotton Mouse (Peromyscus gossypinus)," Proc. Biol. Soc. Wash. Vol. X., pp. 119-125, Nov. 5, 1896. (Records specimens from Bertie county, North Carolina.)

Bangs, O., "A New Race of the Chickaree," Proc. New Eng. Zool. Club, March 31, 1899, Vol. I., pp. 27-29. (Contains references to the Red Squirrels or Chickarees, of Roan Mt., North Carolina.)

Bangs, O., "The Skunks of the Genus Mephitis of Eastern North America," Proc. Biol. Soc. Wash. Vol. X., pp. 139-144, Dec. 28, 1896. (Mentions the absence of skunks from parts of North Carolina.)

Bangs, O., "The Land Mammals of Peninsular Florida and the Coast Region of Georgia," Proc. Bost. Soc. Nat. Hist., Vol. 28, pp. 151-235, March, 1898. (Mentions a number of North Carolina mammals.)

Bangs, O., "A New Race of the Little Harvest Mouse From

West Virginia", Proc. Biol. Soc. Wash., Vol. XII., pp. 167-168, August 10, 1898. (This form may occur in North Carolina.)

Bangs, O., "Notes on the Synonymy of the North American Mink With Description of a New Subspecies", Proc. Bost. Soc. Nat. Hist., Vol. 27, pp. 1-6, March, 1896. (Contains references to Minks from North Carolina.)

Bangs, O., "The Geographical Distribution of the Eastern Races of the Cottontail (*Lepus sylvaticus* Bach.) With Description of a New Subspecies", Proc. Soc. Nat. Hist., Vol. 26, pp. 404-416. (Mentions specimens from North Carolina.)

Bangs, O., "A Review of the Squirrels of Eastern North America", Proc. Biol. Soc. Wash., Vol. X., pp. 145-167, Dec. 28, 1896. (Contains records of *Sciurus niger*, *S. hudsonius*, and *S. carolinensis* from North Carolina.)

Bangs, O., "The Eastern Races of the American Varying Hare, With Description of a Subspecies from Nova Scotia", Proc. Biol. Soc. Wash., Vol. XII., pp. 77-82, March 24, 1898. (Mentions *Lepus americanus virginianus* as occurring as far south as White Sulphur Springs, West Virginia.)

Bailey, V., "Revision of the American Voles of the Genus Microtus", N. Am. Fauna, No. 17, 1900. (Gives North Carolina records of *M. pinctorum*, *M. p. scalopsoides*, *M. pennsylvanicus*, *M. penn. nigrans.*)

Batchelder, C. F., "Some Unrecognized Mice of the Genus Zapus", Proc. New Eng. Zool. Club, Vol. I., pp. 3-7, February 8, 1899. (Mentions *Z. hudsonius americanus* from Raleigh, North Carolina.)

Brimley, C. S., "List of the Mammals of Raleigh, North Carolina", American Naturalist, May, 1897.

Brimley, C. S., "An Incomplete List of the Mammals of Bertie county, North Carolina", American Naturalist, March, 1897.

Coues, Elliott, "Notes on the Natural History of Fort Macon, North Carolina", Proc. Acad. Nat. Science, Philadelphia, May 2, 1871, pp. 1-49.

Elliott, D. G., "A List of Mammals Obtained by Thaddeus Surber in North Carolina, South Carolina, Georgia, and Florida", Field Columbian Mus. Publ. 58, June, 1901.

Howell, A. H., "Revision of the Skunks of the Genus Chincha" (Mephitis), N. A. Fauna, No. 20, 1901. (Mentions *Chincha elongata* from North Carolina.)

Merriam, C. Hart, "Remarks on the Fauna of the Great Smoky Mountains, With Description of a New Species of Redbacked Mouse (Evotomys carolinensis)", Am. Journal of Science, Vol. XXXVI., December, 1888, pp. 458-460. (Applies wholly to North Carolina.)

Merriam, C. Hart, "Description of Twenty-Six New Species of North American Mammals", N. A. Fauna, No. 4, 1890. (Mentions *Spilogale ringens* from Cherokee, North Carolina.)

Merriam, C. Hart, "Synopsis of the Weasels of North America", N. A. Fauna, No. 11, 1896. (Mentions *P. noveboracensis* occurring in North Carolina.)

Merriam, C. Hart, "The Occurrence of Cooper's Lemming Mouse in the Atlantic States", Proc. Biol. Soc. Wash., Vol. VII., pp. 175-177, December 22, 1891. (Mentions specimens from Roan Mt., North Carolina.)

Merriam, C. Hart, "Description of a New Subspecies of Chipmunk", Am. Naturalist, Vol. XX., No. 2, February, 1896. (Mentions a specimen from Jackson county, North Carolina.)

Merriam, C. Hart, "Revision of the Shrews of the Genera Blarina and Notiosorex", N. A. Fauna, No. 10, 1895. (Mentions *B. brevicauda*, *B. carolinensis*, and *B. parva* from North Carolina.

Merriam, C. Hart, "Synopsis of the American Shrews of the Genus Sorex", N. A. Fauna, No. 10, 1895. (Mentions *Sorex fumeus*, *S. personatus*, and *S. longirostris* from North Carolina.)

Miller, G. S., J., "The Longtailed Shrews of the Eastern United States," N. A. F., No. 10, 1895. (Mentions *S. fumeus*, *S. personatus*, and *S. longirostris* from North Carolina.)

Miller, G. S., Jr., "Key to the Land Mammals of Northeastern North America," Bull. N. Y. State Museum, 1900. (Mentions a number of mammals from North Carolina.)

Miller, G. S., Jr., "Revision of the North American Bats of the Family Vespertilionidae," N. A. Fauna, No. 13, 1897. (Contains several North Carolina records.)

Preble, E. A., "Revision of the Jumping Mice of the Genus Zapus," N. A. Fauna, No. 15, 1899. (Mentions *Z. hudsonius*, *Z. h. americanus*, and describes as new *Z. insignis roanensis* from North Carolina.)

Rhoads, S. N., and Young, R. T., "Notes on a Collection of Mammals From Northeastern North Carolina," Proc. Acad. Nat. Sci., Philadelphia, 1897, pp. 303-312.

Rhoads, S. N., "The Marsh or Ricefield Mice of the Eastern United States," American Naturalist, Vol. XXXVI., August, 1902. (Mentions *Oryzomys palustris* from Bertie county, North Carolina, which is an error, as the specimens actually came from Raleigh, Wake county.)

Rhoads, S. N., "Contributions to the Zoology of Tennessee, No. 3, Mammals," Proc. Acad. Nat. Sci., Philadelphia, 1896, pp. 175-205. (Contains records of a number of species of mammals from Roan Mt., North Carolina.)

Rhoads, S. N., "Contributions to a Review of the North American Beavers, Otters and Fishers," Trans. Am. Philos. Soc. N. S., XIX., pp. 417-439. (Describes *Castor c. carolinensis* from North Carolina and refers North Carolina Otters to *L. h. lataxina.*)

True, F. W., "A Revision of the American Moles," Proc. U. S. Nat. Mus., Vol. XIX., pp. 1-112, 1896. (Contains North Carolina records of *Parascalops breweri*, *Condylura cristata* and *Scalops aquaticus.*)

THE METHOXYL GROUP IN CERTAIN LIGNOCELLULOSES.

ALVIN S. WHEELER.

Extended study of lignified tissue has led to the belief that it is essentially a chemical compound and the term lignocellulose is applied to it. The molecule is a very complex one and among the characteristic features of it is the constant proportion of methoxyl, OCH_3. Benedikt and Bamberger* first brought this fact into prominence. The proportion of methoxyl, calculated to methyl, is approximately two and one half per cent. I have extended the work, making determinations in woods mostly native to this country. The Tree of Heaven, China Tree and Paulownia originated in Eastern Asia but are now found wild in this country. The Crab Wood and Wild Lime are native to the Bahama Islands and the West Indies and the samples were obtained from Dr. W. C. Coker.

The determinations were made according to the method of Zeisel. In most cases the wood was taken from small stems. It was cut into small chips, after removal of the bark and dried to constant weight in a steam oven. The values obtained correspond to those of Benedikt and Bamberger. The results are as follows:

Persimmon,	Diospyros Virginiana, L.	1.95
Umbrella Tree,	Magnolia tripetala, L.	2.57
Sassafras,	Sassafras Sassafras (L) Kant	2.44
Chinquapin,	Castanea pumila, (L) Mill	2.16
Buttonwood,	Platanus occidentalis, L	2.23
Witch Hazel,	Hamamelis Virginiana, L	2.67
Pig Nut Hickory,	Hicoria glabra, (Mill) Britton	2.32

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*Monatsh. of Chem. II., 260-267.

Sweet Gum,	Liquidambar Styraciflua, L	2.24
Dogwood,	Cornus florida, L	2.37
Honey Locust,	Gleditsia triacanthos, L	2.47
Tree of Heaven,	Ailanthus glandulosa, Desf.	2.52
China Tree,	Melia Azederach, L	2.35
Paulownia,	Paulownia tomentosa, (Thunb)	2.40
Crab Wood,	Gymanthes lucida,	2.95
Wild Lime,	Fagara flava,	2.19

The average is 2.39 per cent. I wish to thank Mr. Preston Irwin for assistance in making the determinations.

Chapel Hill, N. C.

THE SPONGES OF THE "ALBATROSS" 1891 EXPEDITION.

Memoirs of the Museum of Comparative Zoology at Harvard College, Vol. XXX., No. 1. *Reports on an Exploration off the West Coasts of Mexico, Central and South America, and off the Galapagos Islands*, in charge of Alexander Agassiz, by the U. S. Fish Commission Steamer "Albatross," during 1891, Lieut. Commander Z. L. Tanner, U. S. N., commanding. XXX. *The Sponges*, by H. V. Wilson. Cambridge, U. S. A., 1904. Pp. 164, with 26 plates.

The following synopsis of results is abstracted from the introduction to the above report.

The collection of sponges with which the following report deals has been found to include forty-seven species and subspecies. Of these, twenty-six, representing thirteen genera, fall into the Hexactinellida, seven, representing three genera, fall in the Tetractinellida, and fourteen, representing nine genera, fall in the Monaxonida. No calcareous or horny sponges and no Lithistids were taken. As was to have been expected, since the expedition was made in unexplored waters, a very large percentage of the forms (thirty-three species and subspecies) prove new to science.

LIST OF THE SPECIES TAKEN.

Hyalonema ovuliferum F. E. Sch.
" *pedunculatum*, sp. nov.
" *bianchoratum*, sp. nov.
" *pateriferum*, sp. nov.
" sp. div.
Euplectella, sp.
Regadrella, sp.
" *delicata*, sp. nov.

Caulophacus schulzei, sp. nov.
" sp.
Bathydorus levis spinosus, subsp. nov.
Staurocalyptus sp.
Farrea occa claviformis, subsp. nov.
" *mexicana*, sp. nov.
" sp.
Eurete erectum tubuliferum, subsp. nov.
" " *mucronatum*, subsp. nov.
" " *gracile*, subsp. nov.
" sp.
Aphrocallistes vastus F. E. Sch.
Chonelasma calyx F. E. Sch.
Bathyxiphus sp.
Hexactinella labyrinthica, sp. nov.
" *ventilabrum* Carter.
" *tubulosa* E. E. Sch.
Sclerothamnopsis compressa, gen. et, sp. nov.
Thenea fenestrata(O. Schmidt) Sollas.
" *echinata*, sp. nov.
" *lamelliformis*, sp. nov.
" *pyriformis*, sp. nov.
Poecillastra tricornis, sp. nov.
" *cribraria*, sp. nov.
Penares foliaformis, sp. nov.
Polymastia maeandria, sp. nov.
Petrosia variabilis crassa, subsp. nov.
" *similis densissima*, subsp. nov.
Pachychalina acapuclensis, sp. nov.
Oceanapia bacillifera, sp. nov.
Gellius perforatus, sp. nov.
Tylodesma alba., sp. nov.
" *vestibularis*, sp. nov.
Iophon chilifer ostia-magna, subsp, nov.
" *lamella*, sp. nov.
" *lamella indivisus*, subsp. nov.

Iophon indentatus, sp. nov.
Phakellia lamelligera, sp. nov.
Auletta dendrophora, sp. nov.

In addition to the discovery of new forms, some results of general biological interest have accrued from the study of the collection, and are discussed or stated under the respective species concerned. For convenience of reference the more important of these facts may be here classified.

Remarkable forms. *Hyalonema pedunculatum* is noteworthy for the peculiar pedunculate form of body; *Sclerothamnopsis compressa* for the shrub-like habitus in which it resembles the hitherto unique *Sclerothamnus clausii* Marsh.; *Regadrella delicata* for the character of the sieve-plate region, which may be construed as representing a simpler (although not necessarily a more primitive) phylogenetic condition than the otherwise closely similar *Regadrella phoenix* O. Schm.

Distribution and *Habitat.* *Thenea fenestrata* O. Schm., hitherto known only from the Atlantic and Caribbean Sea, is now recorded for the Pacific. Some of the Hexactinellids from great depths have been found to live clustering upon one another: *Caulophacus* attached to root spicules of *Hyalonema*; *Bathydorus* attached to root spicules of *Hyalonema* and to stalks of *Caulophacus* or similar sponge.

Morphology in general. Further evidence of a convincing character has been gained that the *Eurete* and *Farrea* colonies are derived ontogenetically from simple cup-like forms. ——The close similarity between the main afferent and efferent canals and their apertures in *Poecillastra tricornis* is worthy of remark.——The observations of Sollas and of Dendy on the occurrence of a peculiar fenestrated membrane (Sollas's membrane) in the flagellated chambers of certain sponges have been confirmed for two tetractinellid genera, *Poecillastra* and *Penares*.

Pathological phenomena in general. In *Euplectella* skeletal septa of a reticular character have been found crossing the cavity of the sponge.——In *Chonelasma* similar septa have been observed.——In *Hexactinella labyrinthica* skeletal masses of a reticular character, such as have been especially described by Weltner, occur. In some cases such masses form layers separating one part of the sponge from another.——Possibly all these phenomena are pathological and similar, in so far as they may indicate an effort of the sponge to shut off one one part (diseased?) of the body from the rest.

Morphology of spicules—variations and "*pathological*" *conditions.* In *Hyalonema pateriferum*, pathological amphidiscs such as have been observed by Marshall and Meyer and F. E. Schulze occur. In these spicules several additional rays of the hexact are developed.——Certain details in the structure of the discohexasters of *Caulophacus schulzei* suggest that a hexaster may arise from a hexact through the development of *lateral* branches on the hexact rays.——Another case is afforded by *Hexactinella labyrinthica* of what seems to be the degeneration of an uncinate into an oxydiact.——In scopulae present in *Sclerothamnopsis compressa*, the arrangement of the axial canals indicates that the spicule is equivalent to a branched diact, as Schulze has supposed.——Abundant transitional forms indicate that the protriaenes of *Thenea* are modified *dichotriaenes*.——In *Thenea pyriformis* a type of metaster is common which may be interpreted as transitional between spirasters and euasters.——In *Penares foliaformis* peculiar dichotriaenes are found which approach the shape of the lithistid phyllotriaene.——The occurrence of pathological branching oxeas is recorded for *Petrosia*.

Variation. The variability of sponges in regard to points of adult structure is universally recognized. O. Schmidt and Vosmaer, in particular, have laid stress on the phenomenon as bearing upon the problems of systematic classification. The observations recorded in this report will fall under the following heads:

1. Variation in *body-shape* and *general anatomy*.

Attention may be called to the difference in shape exhibited by specimens of *Hyalonema peteriferum*, *Caulophacus schulzei*, *Thenea fenestrata*, *Petrosia variabilis crassa.*——In *Eurete* the spiral form of body beset with cup-like outgrowths varies towards a bilateral symmetry.——In *Tylodesma alba* massive and lamellate bodies occur, as parts of one continuous specimen.——In *Gellius perforatus* a uniform habit of growth may result in very different body shapes.——In *Thenea* individuals the number and size of pore areas vary; also the spicular fringe round the osculum.——In *Iophon lamella* the character of the surface varies in different parts of the same individual, owing to the divergence in character of the main efferent canals and their apertures, and to the varying amount of collenchyma round such canals.

2. *Variation* in *same individual* in the *skeletal framework*, or the *skeleton in general.*

In *Chonelasma calyx* the tuberculation of the beams of the dictyonal framework varies.——In *Hexactinella ventilabrum* there is considerable variation in the way in which the hexacts combine to form the dictyonal framework.——In *Thenea fenestrata* there is variation in the development of the spicular fringes round the pore areas.——In *Petrosia variabilis crassa* and in *Petrosia similis densissima* a skeletal reticulum remains undeveloped in spots.——In *Pachychalina acapulcensis* the skeletal framework in places is fairly regular, although in general irregular. In *Phakellia lamelligera* the skeletal lamellae vary in respect to branching.——In *Petrosia similis densissima* over some parts of the surface there are no projecting spicules, while over other parts such spicules are present in consideral number.——In *Gellius perforatus* there is considerable variation in the character of the spicular tufts which project from the surface.——In *Iophon lamella* there is variation in the number of spicules which combine to form the side of a skeletal mesh.

3. *Uncorrelated Variation* in the *megascleres* of an *individual*, i. e. variation apparently not correlated with the structural peculiarities of the body-locality.

As regards size of the spicules, there seems to be noticeable variation in all sponge species.——The shape of one of the macramphidiscs varies considerably in *Hyalonema bianchoratum.*——In *Caulophacus schulzei* the principal hexacts are occasionally tuberculated, and in the same species the tuberculation of the pentacts varies.——The character of the diact ends varies commonly, e. g. in *Bathydorus levis spinosus.*——In *Farrea mexicana* the pentacts vary in respect to tuberculation.——In *Eurete erectum* the character of the distal ray of the gastral pinules varies extensively.——In *Petrosia variabilis crassa* the oxea sometimes assumes the shape of a strongyle, or style.——In *Penares foliaformis* the triaenes vary considerably.——In *Pachychalina acapulcensis* the size of the oxea varies within wide limits.——In *Phakellia lamelligera* the oxeas and the two kinds of styles all vary considerably in shape.

4. Uncorrelated variation in the *microscleres* of an *individual.*

The microscleres as well as the megascleres very commonly vary in size and detailed shape, although in them, as in the megascleres, there is a size and pattern which are characteristic of the individual (species), i. e. to which the majority of the spicules of an individual conform.

Some striking cases of variation are afforded by the micro-oxyhexacts of *Hyalonema bianchoratum*, plesiasters and spirasters of *Thenea fenestrata*, sigmata of *Tylodesma alba.*

5. Correlated variation in the *spicules.*

In some cases the variation of spicules is obviously not ungoverned by the rest of the body, but is correlated with body-locality.

Thus while the pentacts in *Hexactinella labyrinthica* vary at large in respect to length of the several rays, the pentacts overlying the larger inhalent canals commonly have noticeably short proximal rays. Such a phenomenon would customarily be referred to as "adaptive."——The variation of dichotriaenes towards the protriaene type, round the pore areas of

Thenea, is another instance of the same phenomenon.——A complex instance of correlated variation is afforded by the dermal and gastral pinules of *Caulophacus schulzei*, which coat the opposite surfaces (pore and oscular) of the body. The two kinds of pinules vary in the same direction in different individuals, and thus the proportionate difference between them is preserved.

6. *Qualitative variation.*

Two sets of individuals living together in the same locality, and which are otherwise indistinguishable, differ conspicuously in respect to a single point. An instance is afforded by *Eurete erectum mucronatum*, which differs from *Eurete erectum tubuliferum* in having oxyhexasters instead of onychasters. Another instance is afforded by *Iophon lamella indivisus*, which differs from *Iophon lamella* only in the character of the bipocillus, which is not chelate.——In order not to confuse the facts with hypothesis, the two sets of individuals have in each case been separated as subspecies. It is idle to dogmatize or to speculate *in extenso* on the value, from the standpoint of heredity, of the point of difference. Whether this point is inheritable and thus marks off two races, or whether it merely marks off two sets of individuals which started out alike and the offspring of which are alike, and which owe their difference to the action on the individual of the environment, no one can say. The recording of the difference is the duty of the systematist, who, when he has done so, has pointed out an additional case suitable for the experimental study of heredity and environmental action.

7. *Variation towards other species or subspecies.*

A class of spicules in one subspecies may vary in considerable number towards a condition characteristic of a subspecies inhabiting a different locality. An instance is afforded by *Eurete erectum gracile*, in which the tuberculation of the gastral pentacts and hexacts is sometimes very similar to that found in the other subspecies of *Eurete erectum*.

Or a form of spicule characteristic of one species may occur infrequently in a related species. For instance, in *Caulophacus schulzei* the pinuli occasionally have the shape characteristic of *C. latus* and *C. elegans*. A striking case is afforded by *Farrea occa claviformis*, in which a few gastral clavulae were found closely similar to the peculiar clavulae of *Farrea convolvulus*.

8. Constancy of *character in spicules.*

It often happens that while in a single individual the *size* of a particular spicule may vary within wide limits, the *character* remains fairly constant—e. g. pinuli of *Hyalonema bianchoratum.*——The character of a spicule even in minute details may apparently become fixed for the species. Thus in a specimen of *Hyalonema ovuliferum* the rays of the micro-oxyhexacts have the same sudden terminal curving exhibited by the corresponding spicules of Schulze's type specimen, although the two sponges were taken 49° of latitude apart. ——A form of spicule which in some sponges varies greatly in size, in other species varies but little. Thus in *Gellius perforatus* the sigmata vary only slightly, whereas in *Tylodesma alba* they vary greatly.

I do not undertake a comparative consideration of the geographical distribution of the forms making up the collection. Such a consideration would demand a knowledge of the actual systematic value to be attached to many *species* recorded in the literature of sponges. And such a knowledge is not to be had at present. In modern sponge literature, e. g. in the two great monographs of Schulze and Sollas (Schulze, 1887; Sollas 1888), the species conceived are, as it seems to me, what H. M. Bernard contends for in his interesting recent discussions (Proc. Cambridge Phil. Soc. Vol. XI. Pt. IV.; Verhdlg. V. Intern Zool.-Congress) of the species-question as affecting the method of recording certain data, viz. homogeneous morphological groups. The sponge species are often very homogeneous, because represented by single specimens. That such groups answer always to natural species, as we understand the word when we speak of the human race, *Passer domesti-*

cus, *Littorina litorea*, or other organisms which we know in great number, is not only open to doubt, but is excessively improbable. It is, I suppose, from this latter point of view (the envisaging clearly the *a priori* probability that sponges in general exhibit those individual and local differences which all species known intimately exhibit) that O. Schmidt was led to record in literature the existence of such species as *Farrea facunda*. Perhaps *Farrea facunda* is a "natural species," but the data at hand make such a statement only a subjective assumption. Or when the distinguished systematist Topsent expresses the opinion that five species of *Poecillastra* recorded by Sollas probably represent the variations of two or three species, one is justified in saying "perhaps, but the known specimens differ in certain definite respects." Such subjective interpretations of differences perhaps always affect the manner in which we record the occurrence of certain morphological peculiarities in association with geographical and bathymetrical site. But whereas once they were rampant, today they are reduced to a minimum, with the result, as I have said, that the *species* of modern sponge literature are strikingly homogeneous groups, which need not be thought of as always corresponding to natural races.

That this method of precise analysis is the only method capable of yielding trustworthy data, seems to me incontestable. That it may result in temporarily recording more species than exist in nature, will only trouble those who incline to the view that the one excuse for systematic zoölogy is to provide them with a handy collection of names for the animal kingdom.

The data which are thus accumulating as to the occurrence of this or that peculiarity of structure in a certain locality are growing rapidly through the labors of systematists. Scarcely begun is the accumulation of the almost equally important data (comp. Poléjaeff, Report on the "Challenger Keratosa," p. 85), as to what peculiarities of structure are due to a difference in the physiological state of individuals belonging to the same race. Such knowledge, to be acquired through continuous observation of living individual sponges under normal and under modified conditions (experimental method) may be expected to bring about the union of many recorded *species.*——Another most important class of data can only be revealed through the physiological study of the *race*, viz. through the breeding of sponges. And with the increase in the number of marine laboratories at which observations may be carried on continuously throughout the year, the inauguration of such studies may be anticipated. ——The modern statistical method of considering the differences between individuals of such groups as are procurable in large numbers is a refinement of what is commonly understood as systematic work, and a promising field for those acquainted with the structure of sponges. Such studies, by revealing the kinds and the extent of structural modifications which occur among individuals not separable into morphologically definable groups, may be expected to provide invaluable special cases for experimental study.——It is through the combination of these several classes of data that we must hope to learn the limits of the natural groups of sponges as as they exist today. When such trustworthy definitions of natural groups are at hand, the facts of the geographical distribution of the species will doubtless become intelligible.

THE ATOMIC WEIGHT OF THORIUM.*

BY R. O. E. DAVIS.

The atomic weight of thorium has been determined with varying results. The values are dependent upon the analyses of the oxalates, sulphates, formate, acetate and acetonyl-acetonate. The first value is due to Berzelius[1] and was obtained from the sulphate and double sulphate of thorium and potassium. The thorium was estimated by precipitation with ammonia and the sulphuric acid as BaS04. The value obtained was 234.8.

In 1861 Chydenius[2] published new determinations from analyses of sulphates, acetate, formate and oxalate. The mean of his determinations gave thorium, 233.1. Two years later in 1863 Marc Delafontaine published some researches on thorium[3]. His studies were particularly on the sulphates. The thorium he estimated in two ways: (1) by precipitation as oxalate and subsequent ignition, (2) by direct calcination. From his work a value of 230.3 for thorium was obtained.

The next determinations were those of Clevé[4]. His work was with the sulphates and oxalates. Next came the work of Nilson[5] on the sulphates. Then in 1887 Kruss and Nilson[6] published determinations. Of the most trustworthy values given by Clarke[7] the value for thorium varies from 223.06 to 236.93, a mean giving the value 232.6.

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*[Dissertation presented to the faculty of the University of North Carolina for the degree of Doctor of Philosophy.

[1] Poggend Annal., 16, 398. 1829.

[2] Poggend Annal, 199, 55. 1863.

[3] Arch. Sci. Phys. et Nat. (2) 18, 343,

[4] Jour. fur Prakt. Chem., 93, 114.

[5] Ber. Deutsch. Chem. Gesell., 15, 2519. 1882.

[6] Ber. Deutsch. Chem. Gesell. 20, 1665, 1887.

[7] Constants of Nature, Part V.

Due to the great variation in values as given by different authorities and determined by different methods, and also the just criticisms which have been lodged against those methods for other elements, it was deemed advisable to redetermine the atomic weight of thorium. We began by first investigating the methods formerly used and then attempted a new method, with what success the sequel will show. In addition to the criticism to which the various methods are subject, recent investigations by Brauner[1] and Baskerville[2], who have been busied for years with the element, point to the complexity of thorium. Moreover the radio-activity associated with thorium is illy understood and appears not to belong to pure thorium compounds.

Of methods used the value 232.6 depends on those of the oxalate, formate, acetate and acetonyl-acetonate. With oxalate, formate, acetate and acetonyl-acetate we have organic compounds with a large number of atoms in the molecules and varying number of molecules of water of crystallization present. For instance, in the oxalate we have $Th(C_2O_4)_2$, $6H_2O$, and the acetonyl-acetonate $Th(C_5H_7O_2)_4$; molecules with thirty-one and fifty-seven atoms in them respectively. It is at once evident that such complex molecules are not satisfactory for atomic weight determinations.

It is upon the sulphate method chiefly that the atomic weight of thorium depends, but the sulphate determinations are open to serious objections. There is objection to using any hydrated salts, because of the uncertainty of the composition. The anhydrous sulphate is objectional because of its porous and deliquescent nature. Yet there are other difficulties of much more importance than these. In most cases the ratio between thorium oxide and sulphate was established by incinerating the sulphate. This is a difficult process and it is extremely doubtful if all the sulphate can be decomposed, as it forms a protective coating of oxide.

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[1] London Ch. Soc. April, 10, 1901.

[2] J. American Ch. Soc., Vol. 23, No. 10., Oct,, 1901.

In some cases the amount of sulphuric acid is determined by precipitation as $BaSO_4$. This is also a very objectionable process, because of the well known property of barium sulphate to occlude foreign substances and hence should be excluded from atomic weight work. While the values obtained from the sulphate method may lie close to the real value of thorium, they probably deviate from it by several points.

From the above considerations it was first decided in this work to make some determinations by the sulphate method in order to test its accuracy. For the material used we are indebted to Dr. H. S. Miner, of the Welsbach Lighting Co., Gloucester, N. J., who generously supplied us with a large quantity of commercial thorium nitrate. This thorium we purified by several of the accepted methods of purification. Half kilo of the nitrate was dissolved in three litres of water and precipitated as hydroxide with ammonia. This was thoroughly washed, then dissolved in HCl. The solution was reprecipitated by ammonia. The other part was neutralized by ammonia until a slight precipitate persisted and the thorium precipitated by the addition of sodium nitrite. The precipitate was thoroughly washed, then dissolved in acid and the precipitation repeated.

One portion we attempted to purify by changing to the chromate, but on subsequent treatment, the chronium was so difficult to remove that this portion was not used in any of our work on the atomic weight of thorium.

Another half kilo, after precipitation by ammonia, was purified by dissolving in ammonium carbonate solution, and then precipitated by ammonia.

Then a portion of this precipitate was purified by the citrate method. A saturated solution of citric acid was saturated with thorium hydroxide and stirred for twenty-four hours. After the citric acid would take up no more thorium hydroxide, the undissolved hydroxide was filtered off, and the filtrate was heated in a water-bath with boiling water. A heavy white precipitate came down. This was filtered through a hot funnel with aid of suction and washed until free from acid. From each of these different sources the thorium was used in the work to be described below.

In this work the crucibles were obtained specially for the purpose and were never used for anything else. The crucible in which the substance was weighed was counter-poised by a crucible as near the same size and weight as possible. The weights were specially standardized by the Bureau of Standards and Weights at Washington and were never used for any other work than this. The balances were adjusted to a constant load and every weight made at that load. The balances were not used for any other purpose after the beginning of this work. The weighings were made by the method of vibrations and were made to 0.000001 of a gramme.

After the purity of our thorium compounds was proven by spectroscopic examination, we first turned our attention to the determination of the atomic weight by the synthesis of the sulphate from the oxide. The method of Gerhard Kruss[1] was used. The oxide was brought to constant weight by heating with a blast lamp, then evaporating with sulphuric acid (1:1) several times to convert all the oxide into sulphate. Then the sulphate was brought to constant weight at a temperature of 360°C. In bringing the sulphate to constant weight, a bath of platinum was used. This bath consisted of a cylindrical tube of copper, about four inches in diameter, mounted above a rose burner, and lined inside with platinum and outside with asbestos. The crucible was suspended in the center of the bath by a ring of platinum wire. The temperature was taken by inserting a mercury thermometer beside the crucible. The mercury was under twenty atmospheres of pressure by carbon dioxide, and the thermometer was graduated to 560°C. It was standardized at the Reichs Anstalt. The results were not strictly concordant and an investigation showed that the ratio between oxide and sulphate varied with the temperature.

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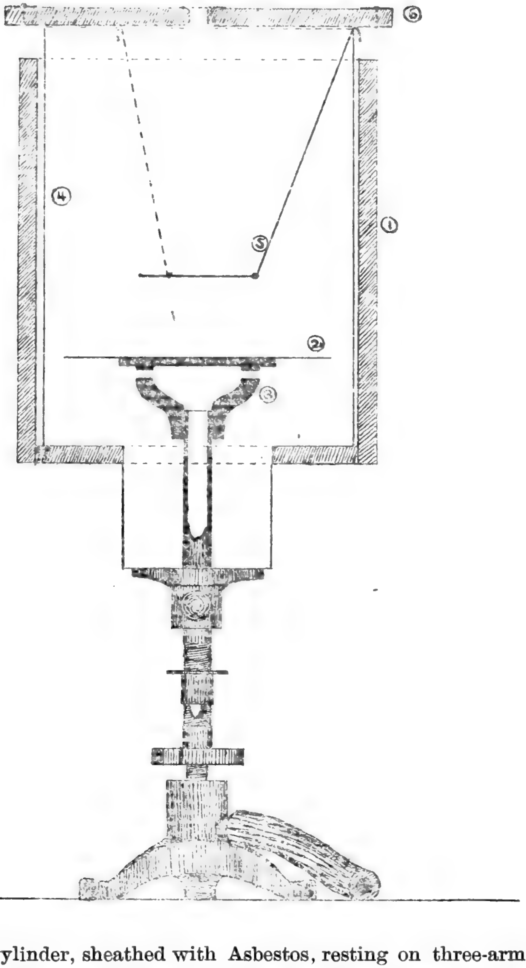
[1] **Chem. News, Jan. 30, 1893. Pp. 32.**



(1) Copper Cylinder, sheathed with Asbestos, resting on three-armed Support, clamped to Bunsen Burner. (2) Platinum Plate, resting on Rose Burner, (3). (4) Platinum Cylinder resting on Asbestos Mat. (5) Platinum Triangle, supported by Platinum Wire Hooks. (6) Asbestos Cover, lined on the inside with Platinum; Hole in center for Thermometer.

Our work seems to indicate that in the formation of the sulphate a mixture is formed. The portion of the sulphate next to the crucible may have been decomposed while the inner portion would still be acid sulphate. Since the atomic weight determinations carried out by other investigators were not made at a definite temperature, then from our investigations the values might have a wide range. Of course, if a series were carried out under exactly the same conditions, concordant results would be obtained. But still there would remain the question whether all the body was normal sulphate or acid or part acid and part basic.

The determination of the equivalent from the acetonyl-acetonate next claimed our attention. The crystals of acetonyl-acetonate were made, but they showed two forms of crystals so that they were not used. The obvious disadvantage of using such a compound has already been mentioned.

After considering the various methods upon which the equivalent of thorium is dependent we decided to try a new method. Of the compounds of thorium considered the tetrachloride seemed to offer the greatest advantages. By its use the ratio could be determined between the oxide and the chloride, and the values of only three elements would be involved.

The thorium oxide was ground up in an agate mortar with carbon (about one-tenth the weight of the oxide) and the mixture placed in a carbon boat. The boat was placed in a hard glass tube passing through a combustion furnace and while heated to a good red heat, dry chlorine passed through the tube. Beautiful crystals of the chloride formed on the walls of the tube just beyond and above the boat. Still farther, lighter and feathery crystals formed in the tube, and a white vapor, Berzelius's "Weisserdampf", was driven off and caught in alcohol.

The carbon used was obtained by heating crystallized rock candy. The boats were previously heated in a stream of dry chlorine for several hours. The chlorine used was taken from an iron cylinder, and was analyzed for oxygen and other impurities. About two per cent. of an inert gas was found, but it was not deemed necessary to remove it. The chlorine was dried by passing over a train of eight towers and wash bottles containing sulphuric, and two towers with glass beads and sulphuric acid, then finally through five towers with glass beads and sulphuric acid, this being the apparatus used by Richards[1] in his work on the atomic weight of cobalt and nickel.

The method of determining the ratio between the chloride and the oxide was to weigh the chloride, dissolve in water and evaporate in a platinum crucible, then ignite to constant weight. The portion of the tube in which the crystals were formed was cut out and slipped quickly into a weighing bottle and then placed in an air bath at 160°C. to drive off the chlorine. It was then removed and placed in a dessicator and after an hour weighed. After weighing the chloride was dissolved in water and then the tube returned to the weighing bottle and brought to constant weight. This gave the weight of the thorium tetrachloride.

The solution of thorium tetrachloride was evaporated in a platinum crucible on the water bath, then ignited to constant weight. In order to bring to constant weight the oxide had to be blasted about seventy hours. This gave the weight of the oxide derived from a given amount of the chloride. But no constant relation could be obtained.

Thinking that perhaps the difficulty lay in not being able to drive off all the chlorine by heat and ignition, we turned our attention to the determination of the halogen. A long series of experiments investigating a new method for the determination of the halogen was begun. Since silver chloride is soluble in water to a certain extent, we decided to investigate its solubility in alcohol.

The alcohol used was absolute and freed from aldehyde by fractional distillation until it would not respond to the fus-

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[1] Proc. Amer. Acad. Arts & Sci. Vol. 34, No. 13, Pp. 332, 1889.

chine test, which shows one part in a million. Silver nitrate solution was made by dissolving pure silver prepared according to the method of Stas by Venable, in pure nitric acid. A solution of $\frac{N}{10}$ NaCl was made for determining the chlorine. Several series of experiments were carried out to determine the effect of an excess of silver nitrate in solution, of acidity, and of temperature. The temperature was varied from boiling to room temperature (about 23°C.).

One cubic centimeter should have precipitated 0.0143 gm. of AgCl. The following are some of the results.

10. AgCl found, 0.756, theoretical, 0.1716; Temp. 30; excess of $AgNO_3$ 0.1028; acidity, 18.5 cc. $\frac{N}{2}$ acid.

12. AgCl found 0.1732, Temp. 30; excess $AgNO_3$ 0.2399; acidity, 20.4cc. $\frac{N}{2}$ acid.

14. AgCl found 0.1800, Temp. 78; excess $AgNO_3$ 0.2183; acidity 25.6cc. $\frac{N}{2}$ acid.

18. AgCl found 0.1754, Temp. 60; excess $AgNO_3$ 0.0171; acidity 25.6cc. $\frac{N}{2}$ acid.

There were twenty-five determinations carried out, all giving too high results, as may be seen from the figures given. By another series of experiments carried out at thirty degrees with rapid filtration, it was found that the results in general agreed with the theoretical. But the conditions were very hard to attain.

We now returned to our thorium and made a series of experiments to determine the chlorine of the tetrachloride. But the results were not concordant, which fact was explained by finding that even aldehyde-free alcohol decomposes silver nitrate, causing finely divided silver to deposit. Of course this method was immediately abandoned.

Now once again we turned our attention to determining the ratio between the chloride and the oxide of thorium by direct evaporation of the chloride solution and the subsequent ignition of the residue to the oxide. But noting that the hard glass tube, in which the chloride was formed, seemed to be attacked by the chlorine at the temperature required for the formation of the chloride, it seemed possible that the disagreement of our values might be due to the formation of other chlorides from the glass. A series of experiments confirmed this view that the glass was causing a contamination of our thorium compound. Hence we set about to eliminate this trouble.

Quartz tubes were imported especially for the work. These were about 2 cm. in diameter and 25 cm. long. In one end of one of these was placed the carbon boat with the mixture of carbon and thorium oxide, and the whole inserted in a porcelain tube and placed in the furnace. The porcelain tube was heated while a stream of dry chlorine was passed through. The "Weisser-dampf" settled on the walls of the porcelain tube, near the end, and the crystals of tetrachloride formed in the quartz tube.

For weighing the chloride, special weighing bottles, 39 cm. long, were obtained. Into one of these the quartz tube was quickly inserted on withdrawing it from the porcelain tube, and after removing the carbon boat. A second weighing bottle was used as counter-poise. The solution of the chloride was evaporated and the final ignition to constant weight was the same as when the glass tubes were used. The water used for the solution of the chloride was purified by redistillation in a platinum still.

The quartz tubes also showed signs of attack by the chlorine at the high temperature used, and so the oxide, after becoming constant in weight, was treated with hydrofluoric acid and the loss in weight, usually very small, applied as a correction to the weights of both the chloride and oxide.

Using every precaution in the work we still failed of constant values, most of them falling between 221 and 230; yet some came lower and some higher than those values. The crystals that seemed to be purest gave values within the limits named. From the inability to obtain a constant value, it seemed that the crystals of chloride must be contaminated. It will be remembered that the crystals of chloride were the middle portion in the formation of the chloride: that is, a light "Weisser-dampf" passed to and condensed on the front of the tube, just beyond the boat were the crystals of the chloride used for the work, and there still remained a residue, mixed with the carbon in the boat, that could not be volatilized. In other words, by distilling thorium oxide in chlorine, three fractions were obtained.

After the first distillation was performed, a determination of the equivalent of each of the end products was made by the sulphate method. The following results were obtained:

Oxide from non-volatile part.	sulphate.	At. Wt.
1.636725 gm.	2.595223	241.44.
Oxide from most volatile.		
0.794692	1.309245	212.70.

As the complexity of thorium had been indicated by Baskerville and the name "Carolinium" proposed for the heavier element, we have applied the name of Carolinium to the heaviest portion. For the lightest the name "Berzelium" was used, and Thorium for the middle portion.

After the redistillation of our carolinium, thorium and berzelium fractions three times, a determination of the atomic weight of each was made by the sulphate method. In changing the oxide into sulphate, sulphuric acid (1:1) was used. This was then carefully evaporated. The berzelium seemed to be rapidly changed; but the thorium and carolinium were more persistent, requiring about four evaporations. In every case sulphuric acid was added and evaporated at least four times, to be sure that all the oxide was converted into sulphate. The carolinium sulphate was perfectly soluble in water, thus showing that all the oxide had been converted into sulphate.

Two determinations of each, carolinium, thorium and berzelium were run at the same time and subjected to the same conditions as nearly as possible. The sulphate of each was heated at 350°C. to constant weight. The platinum bath already described was used and also some large porcelain crucibles with a platinum ring suspended in the center to hold the crucibles. The crucible with the sulphate was placed on this ring, the large crucible covered with a punctured clock glass, and a thermometer suspended through the hole in the glass just above the sulphate inside the small crucible containing it. The results obtained are given below.

The oxides of the three fractions were different in appearance. The carolinium invariably was gray with pink tinge, the thorium slightly greenish, and the berzelium a little more pronounced green. The sulphates of all are pure white when cold, but that of the thorium is yellow while hot.

The following are the results from the determinations:

(1) Carolinium.

Oxide.	Sulphate.	At. Wt.
1.559290	2.434914	255.5
0.524254	0.819365	255.9
0.549331	0.854810	255.6

(2) Thorium.

Oxide.	Sulphate.	At. Wt.
0.425456	0.694936	220.62.
0·740052	1.210405	220.1

(3) Berzelium.

Oxide.	Sulphate.	At. Wt.
0.306778	0.507505	213.6
0.320618	0.530890	212.0

From this it seemed that we were accomplishing the separation of the thorium into three fractions of different atomic weights. The atomic weight of genuine thorium is therefore not yet established.

I wish to express my sincere thanks to Professor Chas. Baskerville not only for his sympathy and assistance in the work, but for the privilege of taking part in an investigation, which has been so fruitful in its results.

University of North Carolina.

VOL. XXI JUNE, 1905 NO. 2

JOURNAL

OF THE

Elisha Mitchell Scientific Society

ISSUED QUARTERLY

CHAPEL HILL, N. C., U. S. A.

TO BE ENTERED AT THE POSTOFFICE AS SECOND CLASS MATTER

Elisha Mitchell Scientific Society.

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Journal of the Elisha Mitchell Scientific Society—Quarterly. Pri
$2 00 per year; single numbers 50 cents. Most numbers of former vo
umes can be supplied. Direct all correspondence to the Edito
University of North Carolina, Chapel Hill, N. C.

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ELISHA MITCHELL SCIENTIFIC SOCIETY.

JUNE, 1905

VOL. XXI NO. 2

PROCEEDINGS OF THE FOURTH ANNUAL MEETING OF THE NORTH CAROLINA ACADEMY OF SCIENCE

HELD AT

A. & M. COLLEGE, RALEIGH, N. C., MAY 12-13, 1905.

MAY 13, 1905.

Meeting called to order by President Stevens at 8:30 P. M., but adjourned for informal conference during which a number of matters were discussed.

MAY 14, 1905.

Meeting called to order at 10 A. M. by President Stevens, who at once appointed Messrs. C. S. Brimley and W. C. Coker as Nominating Committee.

Upon proper presentation of names, Messrs. G. M. Bentley, of the North Carolina Department of Agriculture, at Raleigh, and J. G. Boomhour, of the Baptist Female University also at Raleigh, were elected members.

The Academy then proceeded to the presentation of papers, which were given in the following order:

[Issued September 20th, 1905.]

1. ABNORMALITIES IN THE EMBRYO-SAC OF LILLIUM TIGRINUM: *F. L. Stevens.*

Three abnormalities were noted. In one case the nucleus at the micropilar end of the embryo sac was undergoing constriction while in the spirem stage without any sign of spindle formation. In another case five nuclei, three of these cut off by walls, were in the antipodal end of the embryo sac. Another slide exhibited an excessively long nucleus in the micropilar end of the embryo sac. No explanation was offered. Slides showing the structures referred to were exhibited to the Academy.

2. NOTES ON THE FOOD AND FEEDING-HABITS OF SOME NORTH AMERICAN REPTILES: *C. S. Brimley.*

Personal observation describing how a snake swallows an animal or egg apparently too large for such process. Mentions the food upon which snakes, lizards and turtles have been observed to feed. Describes how a king snake kills another snake.

3. ON THE RECORDED DISTRIBUTION OF CERTAIN INJURIOUS INSECTS IN NORTH CAROLINA: *F. Sherman, Jr.*

Attention was called to the value of positive data concerning the distribution of injurious insects determining the probable results of sporadic out-breaks and informing the prospective planter or orchardist of the pests to be encountered in any particular locality. The Division of Entomology of the North Carolina Department of Agriculture has been keeping accurate records of all reported insect outbreaks for over four years. Some species appear to be generally distributed, others so meagrely recorded as to furnish no conclusions as yet, while still others show fairly well-defined limits.

Notes and maps to illustrate distribution were given as follows:—*Chinch Bug* occurs probably throughout the state east of the mountains, but most destructive in the piedmont section. *Corn Bill-beetle*, probably occurs throughout eastern half of the state, but is chiefly destructive along rivers and streams subject to overflow in the eastern section. *Oyster-shell Bark-louse*, probably occurs throughout the mountain and piedmont sections, but chiefly destructive in the mountains. *San Jose Scale*, occurs in various localities in all sections of the state and has been spread largely by shipment of infested plants. *Strawberry Weevil*, occurs in the strawberry-growing region in the southeast with questionable records for the counties of Wilson, Richmond, and Buncombe.

4. A NEW APPLE-TREE DISEASE. *F. L. Stevens.*

A disease designated as scurf was described. It is an infection of the bark on young twigs, causing a wrinkling and cracking, somewhat resembling the San José scale in appearance. The fungus causing this disease was exhibited in pure plate and tub culture before the Academy. Inoculation experiments are in progress, and a canvas of the state is being made in order to determine the extent of distribution and seriousness of the disease.

Remainder of the papers were withheld to be read at the Joint Session with the North Carolina Section of the American Chemical Society.

The Academy then proceeded with the business of the regular business meeting and upon report of the nominating committee and by ballot the following officers for the next year were elected:

President, PROF. JNO. F. LANNEAU, Wake Forest.

Vice-President, DR. TAIT BUTLER, Dept. Agr. Raleigh.

Secretary-Treasurer, DR. F. L. STEVENS, A. & M. College, West Raleigh.

Executive Committee:—PROF. JNO. F. LANNEAU, *ex officio*, DR. F. L. STEVENS, PROF. COLLIER COBB, Chapel Hill; MR. H. H. BRIMLEY, Dept. Agr., Raleigh; MR. F. SHERMAN, JR., Dept. Agr., Raleigh.

At this point the members of the Chemical Society entered and the Academy proceeded to the business of the joint session, at which the following papers were presented:

1. THE SCIENCE OF PLANT PATHOLOGY, (Presidential Address of President) *F. L. Stevens for the Academy.* (Appears in full in this issue.)

2. A NEW COLOR REACTION FOR LIGNOCELLULOSE: *A. S. Wheeler.*
3. PHYSICS OF SHOOTING STARS: *Jno. F. Lanneau.*
4. CORROSION OF IRON: *R. O. E. Davis.*
5. CONDENSED FORM OF FAT EXTRACTOR AND ETHER RECOVERER: *J. M. Pickel.*
6. BUTTERFLIES OF RALEIGH, N. C.: *C. S. Brimley.*

   In this paper the number of species belonging to each of the families of butterflies was enumerated. Paper was illustrated by specimens prepared in Riker mounts.
7. A PHARMACIST'S VIEW OF PATENT MEDICINES: (summarized only) *E. V. Howell.*

At the conclusion of this program President Williams of the Chemical Section announced the adjournment of both bodies to Giersch's Café where a lunch was tendered the visitors by the Raleigh members of both organizations.

FRANKLIN SHERMAN, JR.,
Retiring Secretary.

THE SCIENCE OF PLANT PATHOLOGY.*

BY PROFESSOR FRANK LINCOLN STEVENS, PH.D.,
North Carolina College of Agriculture.

From the time men first had interest in plants, knowledge of their imperfections or premature death has existed, without, however, definite conception that the imperfections in question really constitute a condition of disease.

The Bible and the early writings of the Greeks and Romans contain references to what we now recognize as wheat rust, fig blight, insect galls and other of the more strikingly conspicuous plant ailments. Such references are more abundant in the literature of the seventeenth century, and in the latter part of that and the eighteenth century a few papers giving careful descriptions of malformations due to insect invasion appeared. Even the law was invoked to aid in combating the wheat rust in France as early as 1660. Prior to the nineteenth century, however, knowledge of plant diseases can hardly be said to consist of more than mere observation of the fact that such diseases occur, and the little real knowledge that did exist was swamped by rampant superstition.

It is natural that the first attempts to explain imperfections were founded upon climatic and soil relations. Vestigial beliefs prevail to this day throughout the country among the untutored to the effect that the various blights, rusts, rots, mildews, etc., are caused solely by untoward conditions of weather, or the unpropitious position of celestial bodies or some other occult influence.

The significance of one great factor in the production of plant disease, namely the parasitic fungi, remained quite unrecognized until the second decade of the nineteenth cen-

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***Reprinted from The Popular Science Monthly, September, 1905.**

tury. Fungi had been seen upon the plant and had been described in some detail during the preceding decade, but instead of being recognized as casual agents of disease they were, as was the fate of bacteria in the case of animal diseases, by many regarded as products of disease. Before the study of plant diseases could be scientifically undertaken, the basic facts of plant nutrition were to be discovered, the parasitic habit of the fungi proved, the minute anatomy of the plant disclosed. Epoch-making in the disclosure of these desiderata, which may be said to have given birth to plant pathology as a science in the second decade of the nineteenth century were the investigations of the early Dutch, French, German and English botanists. Like bacteriology, plant pathology is an infant science of the last century, owing its being to the perfection of the microscope.

In the last two decades of the last century, scientific effort concerned itself chiefly with accumulating knowledge concerning fungi and insects. Vast numbers of these were classified, catalogued and described. In other words, the means of diagnosis were perfected and diseases were grouped into natural classes according to their casual agents. Attempts toward the development of methods of treatment by the use of various sprays were more or less effective. Indeed, spraying had been advocated to some slight extent for a century or more as a remedy for insect and other plant diseases. The variety of spraying substances ranged from clay, ashes and cow manure to sulphur, lime, salt, etc. One writer recommended "The applying around the base of the tree; flax, rubbish, sea weed, ashes, lime, sea shells, sea sand, mortar, clay, tanner's bark, leather scraps, etc."—evidently not a homeopathic prescription. The variety of substances recommended raises suspicion that the efficiency of no formula was demonstrated. In 1787 we find the heroic advice, 'just wet the trees infested with lice, then rub flowers of sulphur upon the insects, and it will cause them all to burst.' Some decided progress was, however, made. As early as 1842, a whale soap was used and retained favor; quassi, hellebore and tobacco were standard insecticides as early as 1855. Sulphur was used for the mildews and bluestone for wheat smut.

The last twenty years of the nineteenth century mark the beginning of a new epoch in plant protection. For this there are three reasons: first, the increased aggressiveness of a certain fungous disease, the grape mildew, in Europe; second, the rapid spread of the potato bug, somewhat pedantically termed the Colorado beetle, and, third, resulting from these two, revolutionary changes in materials and methods for treating plant diseases, both fungous and insect, in the new world and in the old. It is a matter not entirely without interest that the revolution in European methods may be definitely traced to typical American aggressiveness, inasmuch as the activity arousing fungus was of American importation.

In Europe the invasion of the downy mildew of the grape in 1878 was unchecked by the most vigorous fungicides then used. All are familiar with the story of the great benefit conferred upon humanity through the predatory habits of the French boys in the vineyards that produce the famous Bordeaux wines. The rows lying nearest the roadway were sprinkled with verdigris or a mixture of lime and bluestone, to give the impression that the fruit was poisoned. In 1882 Millardet, of the faculty of the sciences, noticed that the vines thus treated held their leaves while others succumbed to the mildew. He ascribed this effect to its proper cause, and conducted carefully systematized experiments, which resulted in giving to the world *bouillie bordelaise*, *Bordelaiser Bruhe*, or Bordeaux mixture, a proved fungicide of great efficiency; one that has not yet been surpassed.

In the new world the extension of the potatoe belt westward connected the eastern potato belt with the region of the native food plant of the familiar potato bug. Finding the potato plant a more abundant and wholesome food than the wild solonaceous plants that it had formerly fed upon, the potato bug began its eastern migration. In 1859 it was found east of Omaha City, in 1868 it had reached Illinois, in 1870 Ontario, in 1872 New York and in 1874 it was upon the Atlantic seaboard. The potato bug ate ravenously and man was stimulated to new activity in the search for more effective means to overcome insect pests. The use of Paris green and London purple followed as a direct result of this stimulus.

The development of efficient fungicides and insecticides in Europe and America led naturally to the perfection of the machines used in applying these mixtures, and not the least important part played in the development of a practical plant pathology is concerned with the evolution of spraying machines. The first sprayer consisted of a bunch of switches. This was dipped into the spraying mixture which was distributed over the foliage by vigorous shaking. It gave place to an improved spraying broom or brush with hollow handle, the liquid flowing from a reservoir to the brush, from which it was applied to the leaves. Sprayers and pumps followed in turn. Then came the improvement of the nozzle.

We may recognize two periods in the development of plant pathology: the first or embryonic period extending from prehistoric times to the beginning of the truly scientific investigations in the middle of the eighteenth century, and contributing chiefly observations, collections, descriptions; the second or formative period, during which the foundations of the science were laid, the chief factors of it determined, and the chief lines of future progress marked out.

It is in no way my purpose to call attention to the part the Carolinas have played in botany as a science, yet I can not refrain in passing from mentioning that prominent place in the history of American mycology is assured to de Schweinitz, a minister of Salem, N. C., who in 1818 published the first important paper on American fungi; to M. A. Curtis, a tutor in Wilmington, N. C., who in 1830, with Berkeley in

England, described many fungi of the Carolinas; to Ravenal, of South Carolina, the first to publish exsiccati of American fungi, and to Louis Bosc, of South Carolina, who published a descriptive list in 1811.

The embryonic and formative period prepared the way for the third period, beginning about 1885, which may be called the period of growth. It is marked by the development and perfection of the rudimentary principals and discoveries of the preceding periods. It was during this period that the most spectacular conquests were made; that popularization and extension of methods occurred. So great, so numerous, so wonderful were the advances made during the past decade, that we frequently see the statement that little or no progress had been made in plant pathology prior to 1885. The present day student should, however, bear in mind that it was the persistent, arduous, patient work of the preceding years that rendered possible the progress of the closing years of the century.

My denomination of this period as 'the period of growth' indicates the nature of the changes which it inaugurates; growth in every direction and concerning every phase of the subject. There has been growth in the list of plant maladies. New diseases have been discovered by scores, and old diseases have been found to affect new plants, and diseases hitherto insignificant have taken prominent places as dangerous foes. The alteration of the plant constitution by high selection and breeding, the bringing of plants into new climatic or soil relations, the more intensive cultivation, the bringing of a susceptible plant into a region where a parasite is already growing upon one of its botanical relatives, thus exposing it to a possible new foe, are conditions that operate to admit of the evolution of new diseases. The growing of plants in large quantities in solid blocks, rather than sparingly in scattered gardens, brings about a congested condition comparable with the crowding of our cities, and favors the development of epidemics* by furnishing abundant material for the parasitic organisms to attack, abundant nutriment upon which they may multiply, and abundant opportunity for them to reach new hosts and spread the contagion. With potatoes, for example, raised merely as garden crops, the probability of an epidemic affecting the majority of gardens is not so great as when potatoes are raised in vast fields. A single field crop, once infested, so contaminates the air with spores that other fields are almost sure to become infected. The contagium becomes sufficiently multiplied to break the quarantine, and a general epidemic results. Any factor which tends to increase the occurrence of epidemics may quickly raise a given disease from obscurity to a position of commanding importance. So, too, dces the increase in value of hitherto comparatively insignificant crops. The pecan and cranberry are at present objects of particular solicitude by the plant physician.

With the importation of plants from foreign countries and the transportation of plants from one part of the country to another comes the possibility of increased disease transference. Recent years have seen the San José scale spread from the Pacific to the Atlantic; the asparagus rust from the Atlantic to the Pacific; the hollyhock rust has invaded us from Europe; the chrysanthemum rust from the Orient; the watermelon wilt is now moving northward and the peach yellows southward. In nearly all cases where the soil is diseased the affected region is annually enlarging, so that soil diseases a decade ago insignificant in the territory of their occupation are fast assuming control of alarmingly large regions. The growing of plants in larger quantities also increase the amount of germ-bearing refuse to the ultimate end that the very air and soil become germ laden.

Civilization, higher culture and community life, especially

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*The use of the word epidemic in relation to plant diseases while etymologically incorrect, seems justified since no other word conveys the desired meaning and the meaning of this word is clear to all.

if it verge upon congestion of population, exacts an inevitable forfeiture by increased mortality. Thus does the list of diseases that comes within the horizon of the practical men enlarge. Wonder, often scepticism, is expressed at the existence of unfamiliar diseases of man, other animals and plants, as though these afflictions were conjured up by the examination of the over zealous practitioner. The increase of affliction is more apparent than real, as it is in the case of appendicitis, which is now recognized, named and cured, consequently, heard of, whereas under the old régime it was not recognized as a distinct disease, therefore it was unheard of, though the patient died. Parallel cases might be cited among the plants.

The work of DeBary on polymorphism among the fungi is being extended. Knowledge of the life histories of various pathogenic fungi is being slowly expanded. Summer forms are connected with winter forms, and thereby the hibernating condition, often the most vulnerable point of attack, exposed. The discovery of heteroecism in the rusts, the alternation from wheat to barberry, from apple to juniper is of classic antiquity in the annals of plant pathology. It emphasized the need of close study of life histories of all parasites. Such study has given abundant fruit, notably in disclosing the relation between the apple cankers and the bitter rot of the apple, and revealing the winter condition of the brown rot of the peach. The lead so fortunately made in the discovery of the Bordeaux mixture has been assiduously prosecuted. The original Bordeaux mixture has been greatly modified, changed, indeed, from a thick paste to a thin solution, and so thoroughly tested in all its modifications, that it has now reached its ultimate perfection. Hundreds of other chemicals, both dry and wet, have been tested as fungicides, with the adoption of a few adapted to special conditions, *e. g.*, sulphur and sulphides for powdery mildews and the ammoniacal copper carbonate for use as the fruit ripens, thus avoiding unsightly spotting. A happy combination of insecticide and fungicide has been found in the various sulphur washes. There has been very remarkable growth in the perfection of spraying appliances; pumps and dusters of many kinds are upon the market. Particularly is the improvement in nozzles to be noted. Nozzles constructed upon scientific principles, capable of applying the liquid in the form of the finest spray to the tops of the highest trees. In the place of the old hand pump and pail we find barrel pumps on wheels, tanks on wheels with pumps operated by gearing attached to the wheels, and finally for the larger fruit farms and for municipal care of shade trees are multiple pumps driven by steam power.

The treatment of seeds to kill adhering spores has been improved upon in many details. It illustrates especially well the nature of the development during the present epoch of plant pathology. Originally the treatment for wheat smut was based purely upon superstition. Pliny, for example, says that 'if branches of laurel are fixed in the ground the disease will pass from the field into the leaves of the laurel.' Tull in 1730 says that there are but two remedies proposed, brining and changing the seed. The avoidance of certain kinds of manure because of their effect upon the host plant and because they carried the smut spores was also advocated about that time. The scientific demonstration by Brefeld that the plant is susceptible only when very small, gave rise to the thought that by hastening the early growth the period of susceptibility could be shortened, and methods of planting and tilling in accord with that idea were advocated. In addition to cultural methods mechanical treatment of seeds, such as passing the wheat loosely between millstones, violent fanning, etc., were suggested about 1786. The chemical treatment of seeds, says Tull, was accidentally discovered about 1660 by the sinking of a shipload of wheat at Bristol, and afterwards, finding it unfit for breadmaking, it was used for seed wheat. The following harvest in England was very smutty except in the case of this accidentally brined seed, which made a clean crop. Then followed brining with liming and liming without brining, soaking in lime, arsenic, salt, arsenic and lye, and various other treatments, none of which, however, came into general use. Accident coupled with acumen again aided in hastening a discovery. Provost while attempting to germinate some spores placed some of them in water distilled in a copper vessel. These failed to germinate, though similar spores placed in water which had not touched copper germinated well. Following this lead he and numerous other investigators experimented extensively with copper compounds during succeding years.

Such is the history of the development of a treatment effective for smut of wheat and barley, but not for that of oats. The next marked advance was made by Jensen, a Dane, who in 1887 developed the famous Jensen hot water treatment, a treatment which though requiring considerable accuracy of manipulation was thoroughly effective. This method, if no easier were to be had, was well worth to practical agriculture all that the experiment stations of the world have ever cost. Within only a few years, however, the Jensen treatment was supplanted by the formalin treatment; a treatment so simple, inexpensive and effective that, save for minor improvements of detail, the end seems to have been reached in the search for preventives for the particular diseases to which the method applies.

Growth of knowledge concerning bacterial diseases has occurred, beginning with the pear blight which baffled all horticulture prior to the assertion of its bacterial nature by Professor Burrill. The proof that bacteria can and do cause plant diseases has been definitely adduced, and a large number of such diseases have been recognized upon many plants. Not only from the scientific side have these ailments been studied, but from the practical as well. and preventive and palliative measures have in many instances been found.

The soil is often spoken of as the living earth. Not only may it live, but it also partakes of those chief accompaniments of life, viz., health, sickness and death. A healthy soil may, from an agricultural point of view, be regarded as one capable of fulfilling all its vital functions; a sick soil, one in which some functions are impaired. Of only one class of soil sickness may I speak, namely, that which results in producing sick plants by harboring pathogenic germs. The cotton wilt, the Texas root rot, the watermelon, tobacco, tomato and cabbage wilts, the cabbage club foot and the onion smut are conspicuous examples of diseases so propagated. Diseases of this type not only destroy the crop, but they preclude the possibility of successful culture of the plant in question, or of its close botanical relatives for many years. Such foes to agriculture have completely destroyed the possibility of tobacco growing on many farms otherwise eminently adapted to this crop and ill adapted to any other, resulting in great depreciation in the value of the land. This encroachment upon valuable soil will proceed yearly, and with geometrically increasing rapidity, until means of prevention are discovered, as they have now been in some instances, and the method of prevention becomes common knowledge. Soil diseases, the most dreaded of all dangers to the plant, are prevalent to much greater extent in the south than in the north. One field is known to exist in South Carolina upon which neither melons, cotton nor cow-peas can be grown. It is conceivable that many other germs could infest one and the same field, but no greater affliction concerning such staple crops seems possible.

Growth in popular appreciation of the importance of plant diseases and of the value of remedial and prophylactic measures is perhaps the most striking characteristic of plant pathology in the last twenty years. At the beginning of this period spraying was in no wise general. It was of rare occurrence. Man suffered unresistingly the attacks of the molds, mildews, rots and blights. The circulation of thousands of state experiment station bulletins and similar bulletins from the national department of agriculture, the vigorous campaign of farmers' institutes, farmers' reading circles, farmers' extension courses, and the extended use of farmers' periodicals and agricultural papers have served to bring the latest discoveries of science to the use of him who will heed. As is to be expected, it is the man who most closely studies his business, he who has most at stake, the large specialist in the culture of any crop, who first embraces the offered aid. The orchardist or vineyardist leads the way in the adoption of new methods and new machinery. The revolution looking toward recognition of the value of plant treatment is now so thoroughly inaugurated that the treatment of such diseases, both insect and fungous, in the case of fruit and trucking crops is of general occurrence. The movement, too, is world-wide.

The practical outcome of all the investigation and propaganda up to the present time is that many hundreds of plant diseases have been recognized; for a hundred or more have been prescribed remedial or preventive measures, many of which are eminently successful; witness, the treatment of cereal smuts, the peach curl, the grape black rot, the powdery mildews. The saving occasioned by any one of these, as is true of scores of others, would amply suffice to pay all the expense of investigation and propaganda incurred in the development of the whole field of plant pathology. By oat smut alone the estimated damage in the United States yearly is $26,766,166, a loss avoidable by an annual expenditure of less than four cents an acre. The saving actually made in Dakota, Minnesota and Wisconsin in one year is placed at $5,000,000.

The future problems of plant pathology are manifold. The period of growth must continue long before the work now undertaken is done. Many diseases of even the cultivated plants are not yet recognized. The diseases of wild plants, particularly the weeds, must too be studied to ascertain the possibility of intercommunication of diseases between weeds and crop plants. The life histories of all disease producing fungi must be closely studied, particularly to determine their hibernating condition. As yet the merest beginning has been made. The interrelation of host and parasite must be studied, the periods, points and modes of infection made known. The biology of the fungi, their life habits, conditions of spore formation, characters of growth, relation to light, heat, moisture, nutriment, etc.; their resistance to adverse conditions, their longevity under various conditions of environment are all problems of ultimate practicality. The question of species is unsettled and the recent demonstration of biologic varieties among the rusts, mildews and fusariums opens a large and important field of research. The agencies operating as disease distributors, the wind, insects, soil, man, water or what not must be known that such distribution be more readily controlled. The causes of resistance and susceptibility to certain diseases rest in obscurity, except in a few cases where the responsibility has been fixed upon some particular structure or chemical. The breeding of plants resistant to specific diseases not readily amenable to other means of control must proceed. Such work is now in progress with cotton, melons, tomatoes, tobacco, grains, flax and other plants. The relation existing between many root fungi and bacteria and the roots they inhabit remains to be studied. Aside from parasitism there is also mutualism, a kind of beneficial disease falling to the province of plant pathology. It needs much further study.

Specific problems also abound, the peach yellows and rosette, the mycoplasm theory of rusts, the grape Brunnisure. Differences of opinion now exist or the technique or scientific data are insufficient for an adequate solution of these questions and many other similar ones. Work on timber protection, while not strictly a question of disease, but rather a post-mortem problem, falls to the lot of the pathologist for the want of a more appropriate place. That intensive study of a disease, however thoroughly it may seem to have been studied before, may lead to important development is well illustrated in the case of the familiar pear blight, which, though known for ages and the topic of masterly classic research, has recently, under trained observation and critical interpretation and experimentation, revealed new secrets leading to more masterful and complete control. The large fields of plant pathology, grouped under the term 'physiological disorders,' are still practically unworked; diseases due to false nutrition, absorption or assimilation, or to impaired carbon assimilation owing to improper environment, to crowding or shading or to hereditary inabilities. A start has been made sufficient to show the importance of the results awaiting.

The recent discovery of the ultramicroscopic organisms or filterable enzymes which has robbed the bacteria of the distinctioin of being the smallest of living things opens a new field in both plant and animal pathology comparable in kind, though probably not in magnitude, with the creation of bacteriology by Pasteur. It is yet unknown whether we have to do here with organisms or enzymes, and contemplation of the problems awaiting in this realm places us in a position to appreciate more fully than ever before the great controversy of spontaneous generation as fought in the sixties. The announcement in a recent periodical of the discovery of soluble protoplasm emphasizes the existence of a vast unknown covered by the words protoplasm, enzymes, invisible organisms. Is it coincidence of fate that with the growing importance of the problem of the invisible organism there comes the invention of a microscope of surpassing excellence with which the seeing of molecules is a hoped for possibility?

The science of plant pathology is indeed young. It has yielded much, and it is still full of promise. In the achievement of the results to come draught will be made upon the sister sciences even more than in the past. Plant physiology waits upon chemistry; plant pathology upon plant physiology, and chemistry in return receives valuable contribution from both. Mathematics, physics and geology all contribute to the general upbuilding. The sciences, though becoming more divergent instead of becoming more independent, are yearly becoming more dependent, each using the discoveries of the others to gain new foothold or new tools in the search for truth. Often it is the frontier territory lying between two sciences which, belonging distinctively to neither, is least worked, and therefore presents most promising territory for conquest. Such is the history of the comparatively new sciences of physical chemistry, physiological chemistry and biometrics.

Nor does the field belong exclusively to either the devotee of pure science, so-called, or of applied science. The study of problems seemingly most remote from any practical ends has often proved fundamental in the upbuilding of vast industrial growth. Bacteriology was born of crystallography. The father of galvanic electricity was derided as the frog's dancing master. Nor does the avowed object in view give a sure key to the ultimate outcome. Alchemy, though never attaining the end sought, hastened immeasurably the era of industrial chemistry. Nor may it be said that applied science is inferior, for without the application the fundamental principles are of no avail in the promotion of the welfare of man.

Intensive laboratory study with no object other than the increase of knowledge of molecular construction has led to the commercial production of many important compounds. The present oat smut treatment by formalin owes its practicability equally to pure science in the chemical study that rendered the production of formalin practicable at moderate cost, and to pure science of the botanist who from mere interest in fungous growth discovered the nature of parasitism, and to the practical scientist who applied the knowledge of the chemist and the botanist to the solution of a definite agricultural problem. The distinction between pure science and applied science is invidious. It is not a difference based upon the nature of the knowledge; rather upon the motive of the worker. All true science is practical, either remotely or directly, and the man of applied science is but completing the work of the pure scientist. Especially does the future of plant pathology rest with both.

A MEMOIR ON THE TWENTY-SEVEN LINES UPON A CUBIC SURFACE.

ARCHIBALD HENDERSON, PH.D.

HISTORICAL SUMMARY.

Although it is probably true that the classification of cubic surfaces is practically complete, the number of articles yearly appearing upon these surfaces furnish abundant proof of the fact that they possess much the same fascination as they did in the days of the discovery of the twenty-seven lines upon the general cubic surface. The literature of the subject is very extensive and in a bibliography* on curves and surfaces, compiled by J. E. Hill, of Columbia University, the section on cubic surfaces contained 205 articles.

The first paper that deals specifically with the cubic surface is one by L. Mossbrugger,† "Untersuchungen über die geometrische Bedeutung der constanten Coefficienten in den allgemeinen Gleichungen der Flächen des zweiten und dritten Grades," which appeared in the first volume of the *Archiv der Mathematik und Physik*, 1841.

The theory of straight lines upon a cubic surface was first studied in a correspondence by the English mathematicians Salmon and Cayley and the results were published, *Camb. and Dublin Math. Journal*, Vol. IV. (1849), pp. 118-132 (Cayley), pp. 252-260 (Salmon). The observation that a definite number of straight lines must lie on the surface is initially due to Cayley, whereas the determination of that number was first made by Salmon.‡

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*Bull. Am. Math. Soc. Vol. III. (1897) pp. 136-146.

†J. E. Hill, l. c.

‡Salmon, Geom. of Three Dimensions, 4th edition, §530, note. Cf. also Cayley, Coll. Math. Papers, Vol. I., note p. 589.

The basis for a purely geometric theory of cubic surfaces was laid by Steiner[*] in a short but extremely fruitful memoir, containing many theorems, given either wholly without proof or with but the barest indication of the method of derivation—a habit of "*ce celebre sphinx*," as he has been styled by Cremona.

On account of the "complicated and many-sided symmetry" among the relations between the twenty-seven lines upon the cubic surface, great difficulty was at first experienced in obtaining any adequate conception of the complete configuration. The notation first given by Cayley was obtained by starting from some arrangement that was not unique, but one of a system of several like arrangements, yet it was so complicated as scarcely to be considered as at all putting in evidence the relations of the lines and triple tangent planes. Hart gave a very elegant and symmetrical notation for the lines and planes, an account of which is to be found in the original paper of Salmon,[‡] who also gave a notation of limited usefulness. Schläfli[¶] it was who invented the notation that might be called epoch-making—that of the double-six,[‖] which has remained unimproved upon up to the present time. This notation is one out of a possible thirty-six of like character among the twenty-seven lines. Taylor[†] has recently given a notation for the lines independent of any particular, initial choice but this cannot be regarded as an improvement upon the Schläfli notation.

The foundations for subsequent analytic investigations concerning the twenty-seven lines were laid, as has been seen, by Cayley and Salmon, and in fact Sylvester[§] once said in

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[*] "Ueber die Flächen dritten Grades," read to the Berlin Academy, 31st January, 1856; Crelle, Bd. LIII.

[‡] Infra, §4.

[¶] Quarterly Journal, Vol. 2 (1858), pp. 55-65, 110-120.

[‖] For the history of the double-six theorem see infra, §6.

[†] Philos. Trans. Royal Soc. Vol. CLXXXV. (1894), part I. (A), pp. 37-69,

[§] Proc. London Math. Soc. Vol. 2, p. 155.

his habitually florid style, "Surely with as good reason as had Archimedes to have the cylinder, cone and sphere engraved on his tombstone might our distinguished countrymen leave testamentary directions for the cubic eikosiheptagram to be engraved on theirs."

The first significant papers on cubic surfaces from the synthetic standpoint, after Steiner's memoir above mentioned, were by Cremona and Rudolf Sturm. These were two of the four papers submitted in competition for the prize offered by Steiner through the Royal Academy of Sciences of Berlin in 1864, which was divided between Cremona and Sturm on Leibniz Day, 1866. The beauty and simplicity of many of the methods employed in these papers eminently justified Steiner's original remark, "Es ist daraus zu sehen, dass diese Flächen fortan fast eben so leicht und einlässlich zu behandeln sind, als bisher die Fläche zweiten Grades." Cremona's "Mémoire de géométrie pure sur les surfaces du troisieme ordre" is found in Crelle's Journal,* whereas Sturm's paper was subsequently expanded into a treatise.†

Schläfli (*l. c.*) first considered a division of the general surface of the third order into species, in regard to the reality of the twenty-seven lines, but he then contented himself with a mere survey of the problem. This was in 1858. But in 1862, F. August‡ gave a rather extended investigation of the subject. In 1863 appeared a valuable memoir by Schläfli,§ treating the subject in great detail. He also, as the title indicates, makes there a division of the surface into types, depending upon the nature of the singularities,—a classifica-

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*Vol. LXVIII. (1868), pp. 1-133.

†"Synthetishe Untersuchungen über Flächen dritter Ordnung." B. G. Teubner, Leipzig, 1867.

‡"Disquisitiones de superficiebus tertii ordinis," Dissert. inaug. Berolini, 1862.

§"On the Distribution of Surfaces of the Third Order into Species, in reference to the presence or absence of Singular Points and the reality of their Lines," Philos. Trans. Vol. CLIII. (1863), pp. 193-241.

tion used by Cayley[*] in his "Memoir on Cubic Surfaces."

If Cayley and Salmon had wished to follow Sylvester's advice and to insert a clause in their wills, directing that a figure of the cubic eikosiheptagram be engraved upon their monuments, they would have had no certainty of the correct fulfilment of their directions until the year 1869 when Dr. Christian Wiener[‡] made a model of a cubic surface, showing twenty-seven real lines lying upon it. This achievement of Dr. Wiener, Sylvester[¶] once remarked, is one of the discoveries "which must forever make 1869 stand out in the Fasti of Science." Since that time, there have been constructed models of all the various types of the cubic surface, showing the lines lying entirely upon them. The list of those who have written on the mechanical construction of the configurations of the lines upon a cubic surface and the general subject of the collocation of the lines upon the surface includes the names of Salmon, Sylvester, Cayley, P. Frost, Zeuthen and Blythe.[||]

The configuration of the twenty-seven lines is not only of the highest interest *per se*, but also on account of its close association and relation to other remarkable configurations. It was also in the year 1869 that Geiser[§] showed the mutual interdependence of the configurations of the twenty-eight bitangents to a plane quartic curve and the twenty-seven lines upon a cubic surface, and the method of derivation of each from the other. By making use of Geiser's results, Zeuthen[†] obtained a new demonstration of the theorems of Schläfli[††] upon the reality of the lines and tripletangent planes

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[*] Philos. Trans. Royal Soc. London, Vol. CLIX. (1869), pp. 231-326.

[‡] Cf. Cayley, Trans. Camb. Philos. Soc. Vol. XII. Part I (1873), pp. 366-383, where a description of the model is given.

[¶] Proc. London Math. Soc. Vol. 2, p. 155.

[||] Cf. infra, §§18-21.

[§] Math. Ann. Bd. I. (1869), pp. 129-138.

[†] Math. Ann. Bd. 7 (1874), pp. 410-432.

[††] Quarterly Journal, Vol. 2, (1858); Philos. Trans. Vol. 153 (1863).

of a cubic surface. Indeed, it is feasible to derive the properties of one configuration from the known properties of the other.[*]

In 1877 Cremona[‡] first showed that the Pascalian configuration might be derived from the configuration of the twenty-one lines upon the surface of the third degree with one conical point (Species II., Cayley's enumeration) by projection from the conical point.

The theory of *varieties* of the third order, that is to say, curved geometric forms of three dimensions contained in a space of four dimensions, has been the subject of a profound memoir by Corrado Segre.[¶] The depth of this paper is evinced by the fact that a large proportion of the propositions upon the plane quartic and its bitangents, Pascal's theorem, the cubic surface and its twenty-seven straight lines, Kummer's surface and its configuration of sixteen singular points and planes, and on the connection between these figures are derivable from propositions relating to Segre's cubic variety, and the figure of six points or spaces from which it springs.[†] Other investigators on this beautiful and important locus in space of four dimensions and some of its consequences are Castelnuovo and Richmond.[§]

The problem of the twenty-seven lines is full of interest from the group theoretic standpoint. In 1869 Camille Jordan[||] first proved that the group of the problem of the trisection of hyperelliptic functions of the first order is isomorphic with

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[*] Crelle's Journal, Vol. 122 (1900), pp. 209-226.

[‡] Reale Accademia dei Lincei, Anno CCLXXIV. (1876-77). Roma. Also cf. infra, §§47, 48.

[¶] Atti d. R. Accad. di Scienze di Torina, Vol. XXII. (1887), pp. 547-557. Memorie d. R. Accad. di Scienze di Torino, Series 2, Vol. XXXIX. (1889), pp. 3-48.

[†] Richmond, Quarterly Journal, Vol. XXXIV. No. 2 (1902), pp. 117-154.

[§] Cf. Richmond l. c. for references.

[||] Comptes Rendus, 1869. Cf. also Traite des Substitutions, p. 216 et seq., p. 365 et seq.

the group of the equation of the twenty-seventh degree, on which the twenty-seven lines of the general surface of the third degree depend. Felix Klein† in 1887 sketched the effective reduction of the one problem to the other. In 1887-9 Maschke‡ in a series of papers set up the complete form-system of a quaternary group of 51840 substitutions, and in 1893 Burkhardt,‖ on the basis of Klein's paper above mentioned, these papers of Maschke and one by Witting,§ carried out the work sketched by Klein—the reduction of one problem to the other.

Since Jordan's first paper appeared in 1869, a number of writers have studied the Galois group of the equation of the twenty-seven lines. Dickson** has led in this investigation, publishing a number of papers on the subject. Other writers on the same subject are Kühnen,†† Weber,‡‡ Cartan and, more recently, Kasner. This last paper is in close contact with the investigations of Moore and Slaught on the cross-ratio group of Cremona transformations.

INTRODUCTION.

The problem of the twenty-seven lines upon a cubic surface is of such scope and extent and is allied to so many other problems of importance that to give a *resume* of all that has

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†Extrait d'une lettre addressee a M. C. Jordan, Journal de Liouville, series 4, tome IV. (1888), p. 169 et seq.

‡Math. Ann. Bd. XXX. (1887), pp. 496-515; Gött. Nach. (1888), pp. 76-86; Math. Ann. Bd. 33, (1889), pp. 317-344.

‖Math. Ann. Bd. 41 (1893), pp. 309-343.

§Math. Ann. Bd. 29 (1887).

**Trans. Am. Math. Soc. Vol. 2 (1901), pp. 137-138; Quarterly Journal Vol. 33 (1901), pp. 145-173; Bulletin Am. Math. Soc. Vol. 8 (1901), p. 63 et seq.; Linear Groups Ch. XIV. pp. 303-307.

††"Uber die Galois'che Gruppe der Gleichung 27 Grades, von welcher die Geraden auf der allgemeinen Fläche dritter Ordnung abhängen," Diss. Marburg, 1888.

‡‡Math. Ann. Bd. XXIII., pp. 489-503.

been done upon the subject would enlarge the present paper into a book. It was found impossible to cover even the geometrical phases of the problem, in their extension in particular to the cognate problem of the forty-five triple tangent planes, although the two subjects go hand in hand. In this memoir, however, is given a general survey of the problem of the twenty-seven lines, from the geometric standpoint, with special attention to salient features, i. e., the concept of trihedral pairs, the configuration of the double-six, the solution of the problem of constructing models of a double-six and of the configurations of the lines upon the twenty-one types of the cubic surface, the derivation of the Pascalian configuration from that of the lines upon the cubic surface with one conical point, and certain allied problems.

In §§ 1-4 are given certain preliminary theorems concerning the existence and number of the twenty-seven lines and forty-five planes for the general cubic surface, and upon the first notation employed. In §§ 5, 6 and 7 are given an account of Schläfli's notation, a history of the double-six theorem and an analytic proof of it, independent of cubic surfaces; in §8 follow certain interesting results on the anharmonic ratios of the configurations. In §9 appear two conditions that five lines lie upon a cubic surface and in §10 is the description of the formation, and the tabulation of the thirty-six double-sixes. In §11 occur certain auxiliary theorems for special features of the general configuration of the twenty-seven lines.

In §12 are given the definition and number of trihedral pairs, and in §13 the actual formation of the tables of the 120 forms. In §14 these are grouped together in such a way (sets of three) as to determine in forty ways all the twenty-seven lines.

In §16 is given a discussion of a special form of the general equation of the cubic surface and the determination of the equations of the forty-five triple tangent planes.

In §§18 and 19 the methods for the construction of a model of a double-six are discussed and a practical method is there given in detail.

In §§20 to 45 the general problem of constructing thread or wire models of the configurations of the lines upon all twenty-one types of the cubic surface is fully considered, and a complete solution of the problem given.

In §46 is given a discussion of the derivation of the Brianchon configuration from two spatial point triads, and in §§47-8 the discussion of the derivation of the Pascalian configuration from that of the straight lines upon the second species of the cubic surface (Cayley's enumeration) and a graphic representation of the same.

Finally, in §49 appears a theorem on the number of cubic surfaces with one conical point passing through the lines of mutual intersection of two triheders.

CHAPTER I.

PRELIMINARY THEOREMS.

§1 *Existence of Straight Lines upon a Cubic Surface.*

In order to find the conditions that any straight line, whose equations are

$$\frac{x - x_0}{\lambda} = \frac{y - y_0}{\mu} = \frac{z - z_0}{\nu} = r,$$

lie entirely upon a surface, we substitute $x = x_0 + \lambda r$, $y = y_0 + \mu r$, $z = z_0 + \nu$ in the equation of the surface, arrange the terms of the resulting equation according to powers of r and then set all the coefficients of r equal to zero, since the equation in r must be identically satisfied, i. e., for all values of r. Since in this case the equation of the surface is of the third degree, there result four conditions. But the equations of a straight line involve four disposable constants, and, as the number of conditions to be fulfilled is exactly equal to the number of disposable constants in the equations of the straight line, it follows that every surface of the third order must contain a finite number of straight lines, real or imaginary, lying entirely upon it.

§2. *Number of Straight Lines upon a Cubic Surface.*

Suppose we pass a plane π through a point P outside the surface and through a straight line l lying upon the surface. Then π meets the surface in the line l, and a conic C besides (since the curve of intersection is a degenerate cubic), i. e. meets the surface in a section having two double-points and therefore by definition is a double-tangent plane. These double-tangent planes π to the cubic surface are also double-tangent planes to the tangent cone, vertex P. Now since to every plane π corresponds one straight line l lying entirely on the surface and as there are twenty-seven* ($n = 3$) double-tangent planes to the tangent cone, vertex P, therefore there are twenty-seven straight lines l on the cubic surface.†

§3. *Triple Tangent Planes.*

By properly determining the plane passed through any straight line l upon the cubic surface, the conic C (§2) will

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*Salmon, Geom. of Three Dimensions, 4th edition, §286 gives

$$\frac{n}{2}(n-1)(n-2)(n^3-n^2+n-12)$$

as the number of double-tangent planes, drawn through a point P to a surface of the nth degree.

†For other proofs compare R. Sturm, Flächen dritter Ordnung, Kap. 2, §20, and Cayley, Coll. Math. Papers, Vol. I., No. 76 (445-456).

degenerate into a pair of straight lines. Here the plane intersects the surface in three intersecting straight lines (a degenerate curve of the third order having three double points) and the points of intersection of the lines taken in pairs are the points of contact of the plane with the surface. Now through each of the three lines in the plane there may be drawn, besides the given plane, four triple tangent planes. For these twelve new planes give rise to twenty-four new lines upon the surface, making up with the former three lines, twenty-seven lines upon the surface. It follows that every straight line on the surface is met by ten others.

If all the twenty-seven lines intersect in pairs, there would be 351 points of intersection. But since each line is met by ten other lines, there remain 16 lines by which it is not met and therefore there are $\frac{27 \times 16}{2} = 216$ pairs of lines that do not intersect. Consequently there are 135 points of intersection.

Since these 135 points, by threes, determined the triple tangent planes, there are 45 triple tangent planes.

Consider the three lines a, b, and c say, the complete intersection of the triple tangent plane π with the surface. Then every other line l upon the surface must meet the triple tangent plane in a point upon one (a say) of the three lines a, b, and c, and accordingly must lie in a plane π_l, passing through a. Since the intersection of the surface by the plane π_l must be a cubic curve, which is already composed of two straight lines, the plane π_l meets the surface in a third straight line l', and therefore must be a triple tangent plane. Hence l' must be one of the given 27 lines and it appears that there can be but 27 lines upon a cubic surface.

§4. *Salmon's Notation for the Twenty-Seven Lines.*[*]

Lemma. *The general equation of the cubic surface may be*

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[*] Camb. and Dublin Math. Journal (1849), Vol. IV., pp. 252-260.

reduced to the canonical form $uvw - \xi\eta\zeta = 0$, *where* u, v, w, ξ, η, ζ *are linear polynomes.*

The number of independent constants in the general equation of the third degree is $19\left[\frac{n\,(n^2 + 6n + 11)}{6}, \text{ for } n = 3\right]$. Since the linear polynomes u, v, w, ξ, η, ζ contain 18 ratios of coefficients and there is one other constant factor implicitly contained in one of the products uvw, $\xi\eta\zeta$, therefore the forms $uvw - \xi\eta\zeta = 0$ contains 19 constants and is one into which the general equation of a cubic surface may be thrown.

It will appear later (§15) from geometrical considerations that the problem to reduce the base cubic to the form $uvw - \xi\eta\zeta = 0$ is soluble in 120 different ways.

NOTATION. Consider the canonical form of the surface of the third degree $ace - bdf = 0$, where a, b, c, d, e, f are linear polynomes. By inspection it is patent that this surface contains the nine lines ab, ad, af, cb, cd, cf, eb, ed, ef where ab, for example, represents the line of intersection of the planes $a = 0$, $b = 0$. If we suppose $a = \mu b$ to be the equation of one of the triple tangent planes through the intersection of the planes a and b, the plane $a = \mu b$ meets the surface in the same lines in which it meets the hyperboloid $\mu ce - df = 0$, that is, the two lines in the plane are generating lines of different species, and consequently one of them meets the pair of lines cd and ef, and the other of them meets the pair of lines cf and ed. Let us now denote each of the remaining eighteen lines by the three lines which it meets, the line meeting ab, cd and ef being denoted by the symbol $ab \cdot cd \cdot ef$. Since μ has three values, there are three lines that meet ab, cd, ef. Applying the same reasoning to the planes through bc and ca, we employ the following symbolism for the twenty-seven lines ab, ad, - - - - - ef; $(ab \cdot cd \cdot ef)_i$, $(ad \cdot cf \cdot eb)_i$, $(af \cdot cb \cdot ed)_i$, $(ab \cdot cf \cdot ed)_i$, $(ad \cdot cb \cdot ef)_i$, $(af \cdot cd \cdot eb)_i$, where $i = 1, 2, 3$.

Unfortunately our information as to how these suffixes are to be applied is inadequate and certain postulates have to be made as to how the intersections occur.* This notation of Salmon was the first one that was given for the twenty-seven lines, and was superseded by a very superior one to be explained in the next article.

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*Cf. Salmon, l. c.

MOLECULAR ATTRACTION, IV., ON BIOT'S FORMULA FOR VAPOR PRESSURE AND SOME RELATIONS AT THE CRITICAL TEMPERATURE.[1]

J. E. MILLS.

THE $\frac{\delta P}{\delta T}$ OF A LIQUID.

In a preceding paper[2] we examined the following equation, which had been proposed on theoretical grounds by Mr. H. Crompton,

$$[1] \qquad L = 2\int_v^V p\delta v = 2\,RT\log_e\frac{d}{D} = \frac{9.154}{m}T\log\frac{d}{D}\text{ cals.}$$

(L is heat of vaporization, v and V denote volume of liquid and vapor, d and D the density of liquid and vapor, p is pressure, T is temperature, m is molecular weight, R is the constant of the gas equation, $PV = RT$.)

It was there shown that this equation gives at low temperatures where the pressure is small, results for the heat of vaporization that are invariably and usually very considerably too large. But at the higher temperatures examined, that is as the critical temperature is approached, the results given by the equation appeared to be correct. The evidence there given as to the correctness of this equation at high temperatures was very considerable and justified further use of the equation. Therefore in this paper we combined the usual thermodynamical equation for calculation of the heat of vaporization,

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[1] Reprinted, with omission of a Table, from Jour. Phys. Chem., 9, p. 402, 1905.

[2] Jour. Phys. Chem. 8, 593 (1904).

$$[2] \qquad L = \frac{T}{J}(V - v)\frac{\delta P}{\delta T} = .0_4 31833\, T\,(V - v)\frac{\delta P}{\delta T} \text{ cals.}$$

with the equation of Crompton given above, and obtained equation 15 of that paper, viz.:

$$[3] \qquad \frac{\delta P}{\delta T} = \frac{287500}{m}\,\frac{\log\frac{V}{v}}{V - v}$$

We there showed that the limit approached by this equation as the critical temperature was approached and V approached v in value, was,

$$[4] \qquad \frac{\delta P}{\delta T} = \frac{124860}{mV}.$$

We at that time overlooked the fact that this equation 4 could be expressed in the very simple form,

$$[5] \qquad \frac{\delta P}{\delta T} = \frac{2R}{V}.$$

Here V is the critical volume and R is the usual gas constant, and we have the striking conclusion that *at the critical temperature the* $\frac{\delta P}{\delta T}$ *of the liquid (vapor) is exactly twice what it would be for that substance as a perfect gas occupying the same volume.* Expressed in this form the bearing of equation 3, or its limiting forms, on the kinetic relations of a liquid and its vapor, assumes more importance and justifies a closer study.

Accordingly by means of equation 4, we calculated, and give in Table 1, the values of the $\frac{\delta P}{\delta T}$ at the critical temperature for twenty substances. The critical data used is that given by Dr. Young[1]. This data is more correct than that given in earlier papers. (We would here note that in the third paper on Molecular Attraction[2] we overlooked this corrected data, but have since repeated the calculations there given

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[1] Phil. Mag., [5], 50, 291 (1900).

[2] Jour. Phys. Chem., 8, 593, (1904).

using the corrected data and find no material change in the results or conclusions there expressed.)

For comparison with these values the $\frac{\delta P}{\delta T}$ can be calculated from any equation connecting vapor pressure and temperature. Of the numerous equations that have been proposed the one usually known as Biot's has proved by far the most serviceable. It takes the form,

$$\text{Log } P = a + b \, . \, \alpha^t + c \, . \, \beta^t. \tag{6}$$

By differentiating and changing to Naperian logarithms we get,

$$\frac{\delta P}{\delta T} = 5.3019 \, P(b \, . \log \alpha \, . \, \alpha^t + c \, . \log \beta \, . \, \beta^t). \tag{7}$$

Since we had previously used Biot's formula for calculating heats of vaporization more directly, we found it easier to throw equation 7 into the form,

$$\frac{\delta P}{\delta T} = .031414 \, P \, A, \tag{8}$$

where, $A = 168.775 \, (b \, . \log \alpha \, . \, \alpha^t + c \log \beta \, . \, \beta^t)$. The constants for this equation have already been given[1] for all of the substances examined except those noted below.

Ethyl oxide. $A = \text{antilog } (\bar{1}.9882227 - .00172541 \, t)$
$+ \text{antilog } (\bar{1}.7399799 - .00869664 \,),$
$t = t^\circ$ C.

Benzene. $A = \text{antilog } (\bar{1}.4256719 + .0001302029 \, t)$
$+ \text{antilog } (0.1799122 - .00410411 \, t),$
$t = t^\circ$ C.

Methyl alcohol. $A = \text{antilog } (\bar{1}.5561254 - .00011584 \, t)$
$+ \text{antilog } (.2.51667 - .00400204 \, t),$
$t = t^\circ$ C.

Ethyl alcohol. $A = \text{antilog } (\bar{2}.3965216 + .003377538 \, t)$
$+ \text{antilog } (0.3342413 - .00317576 \, t),$
$t = t^\circ$ C.

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[1] Jour. Phys Chem., **8**, 383 (1904).

Propyl alcohol. $A = \text{antilog}\,(\bar{2}.8340346 + .001641423\,t) + \text{antilog}\,(.03135244 - .00342975\,t)$, $t = t^\circ\,C - 20$.

The constants for ethyl formate and methyl acetate were kindly sent me by Dr. Young (work yet unpublished) and the constants for methyl formate I have calculated and will publish later.

The values of the $\frac{\delta P}{\delta T}$ at the critical temperature as obtained from these Biot equations are shown in Table 1.

Of the twenty substances compared in Table 1 it will be seen that the $\frac{\delta P}{\delta T}$ from equation 4 has a higher value than the $\frac{\delta P}{\delta T}$ calculated from Biot's formula in all cases except di-isobutyl, normal octane, and ethyl alcohol. The difference is usually very marked.

In work done upon an equation of the form, $P = bT - a$, Ramsay and Young[1] made a study of the $\frac{\delta P}{\delta T}$ of ether at constant volume, Young[2], later, a similar study for isopentane, and Rose-Innes and Young[3] corresondingly for normal pentane. At the critical volume the values of the $\frac{\delta P}{\delta T}$ obtained at constant volume becomes identical with the value of the $\frac{\delta P}{\delta T}$ denoting the increase in vapor pressure of the liquid. Therefore it is possible in these three cases by comparison with the values of the $\frac{\delta P}{\delta T}$ obtained in the above papers to determine whether the values of the $\frac{\delta P}{\delta T}$ calculated from Biot's

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[1] Phil. Mag. [5], **23**, 435, (1887).

[2] Ibid, [5], **38**, 569, (1894).

[3] Ibid. [5], **47**, 353 (1899).

TABLE 1.

SUBSTANCE	Critical Temperature	$\frac{\delta P}{\delta T}$ from Equation 4	$\frac{\delta P}{\delta T}$ from Biot	Δ	A
Ethyl oxide...	194.45°C	441.9	391.6	50.3	.46068
Di-isopropyl	227.35	349.6	321.0	28.6	.43795
Di-isobutyl	276.8	258.8	261.6	—2.8	.44672
Isopentane	187.8	405.7	367.8	37.9	.46822
Normal pentane	197.2	402.3	364.8	37.5	.46331
Normal hexane	234.8	339.9	315.9	24.0	.44826
Normal heptane	266.85	291.9	286.9	5.0	.44782
Normal octane	296.2	254.5	256.8	—2.3	.43647
Benzene	288.5	487.0	445.4	41.6	.38961
Hexamethylene	279.95	406.0	376.0	30.0	.39583
Fluo-benzene	286.55	460.1	430.7	29.4	.40428
Carbon tetrachloride	283.15	452.7	416.7	36.0	.38808
Stannic chloride	318.7	355.2	332.5	22.7	.37689
Methyl formate	214.0	725.6	619.2	106.4	.43872
Ethyl formate	235.3	545.0	479.7	65.3	.43091
Methyl acetate	233.7	548.3	502.3	46.0	.45454
Methyl alcohol	240.0	1061.1	971.1	90.0	.51729
Ethyl alcohol	243.1	747.0	796.7	—49.7	.52998
Propyl alcohol	263.7	568.3	562.4	5.9	.47181
Acetic acid	321.65	729.2	574.6	154.6	.42066

formula or those obtained from equation 4 are correct. The result is shown below, the value of the $\frac{\delta P}{\delta T}$ at the exact critical volume having been obtained from the above mentioned papers by interpolation and entered in the column marked 'Observed".

Substance	Volume	From Biot	Equ'tion 4	Observed
Ether	3.815	391.6	441.9	436
Isopentane	4.268	367.8	405.7	401 to 411
Normal pentane	3.305	364.8	402.3	406.7

In every case the values accord to within the limit of experimental error with the values derived from Biot's equation. (It is not possible to extend the comparison to the alcohols and acetic acid studied by the observers above mentioned, for these liquids are associated and equation 4 depending on the molecular weight, could not give correct results.

ON BIOT'S FORMULA FOR VAPOR PRESSURE.

It seemed to us reasonable to conclude from the above comparison that the ratios of the $\frac{\delta P}{\delta T}$ calculated from equation 4 at the critical temperature and shown in Table 1 were the correct values and that the values obtained from Biot's formula were in error. Fortunately we had a means of verifying this conclusion directly.

If the vapor pressure curve be plotted, the $\frac{\delta P}{\delta T}$ is the tangent to the curve. Assuming that Biot's formula does correctly represent the vapor pressures until the critical temperature is approached (an assumption justified by a very careful examination of the curves over the entire range of temperature) it is evident that if the $\frac{\delta P}{\delta T}$ calculated from Biot's formula then becomes too low it must be because the vapor pressure curve as calculated from Biot's formula is below the true vapor pressure curve. We accordingly subtracted the observed vapor pressures from the calculated in the immediate neighborhood of the critical temperature. (These results are shown in detail in Table 2, Jour. Phys. Chem. 9, p. 402 [1905]). In every case except normal octane, stannic chloride, and the associated substances (methyl alcohol, ethyl alcohol, and acetic acid), the calculated minus the observed vapor pressures does give negative differences at the highest temperature compared (usually the critical temperature itself). With regard to these five exceptions, the associated substances cannot give exactly correct results by the use of equation 4 and their evidence does not therefore bear upon that equation. Normal octane and stannic chloride are the only substances whose divergence can be considered as evidence against the conclusion above derived and it is sufficient to point out in explanation a remark made by Dr. Young[1] when the vapor pressures of normal octane were published. He there states that the observed values of the vapor pressure above 280° C for *normal octane, stannic chloride, and acetic acid*, are probably *too low* owing to an error in the temperature scale, i. e., in the boiling points of the liquids used as a heating jacket.

A close examination of the observed and calculated vapor pressure curves reveals the fact that no matter how the constants for Biot's formula be altered they cannot exactly represent the true vapor pressures in the neighborhood of the critical temperature. The deviation is very slight, usually negligible when the vapor pressure is considered, because the proportional error is very small. But when the $\frac{\delta P}{\delta T}$ is considered the proportional error is very large.

Since Biot's formula was empirical and in the immediate neighborhood of the critical temperature was forced to fit a curve it could not exactly follow it usually happens that the

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[1] Jour. Chem. Soc., **77**, 1147 (1900).

TABLE 2.

SUBSTANCE	Temperature	Old μ'	New μ'	Mean μ'	Critical Temperature	μ' From Equation 12	$\frac{P\,V\,m}{T}$
Ethyl oxide	193	90.7	102.0	104.4	194.4	102.1	16360
Di-isopropyl	225	92.0	96.8	98.1	227.4	96.5	16660
Di-isobutyl	274	86.4	82.3	86.3	276.8	80.7	16370
Isopentane	187.4	99.3	107.0	105.4	187.8	107.0	16710
Normal pentane	197	98.8	109.9	109.9	197.2	109.4	16570
Normal hexane	234	94.2	99.5	102.85	234.8	99.2	16290
Normal heptane	266.5	90.8	91.0	98.75	266.9	90.8	16170
Normal octane	290	91.0	84.8	93.0	296.2	84.2	16140
Benzene	280	107.8	111.2	109.5	288.5	110.5	16610
Hexamethylene	279	98.1	104.7	103.6	280.0	104.5	16820
Fluo-benzene	280	84.7	85.75	85.6	286.55	85.2	16440
Chlor-benzene	....	....	....	81.2	360.0	81.5	16490
Brom-benzene	....	....	....	56.1	397.0	56.3	16380
Iodo-benzene	....	....	....	44.4	448.0	43.8	16500
Carbon tetrachloride	280	43.9	45.5	44.1	283.15	45.3	16940
Stannic chloride	280	22.15	26.96	26.04	318.7	25.87	16680
Methyl formate	213.5	101.2	120.1	121.5	214.0	119.8	15910
Ethyl formate	234	94.0	104.4	107.2	235.3	103.9	16040
Methyl acetate	233	96.6	103.8	109.5	233.7	103.6	15800
Methyl alcohol	238.5	259.4	264.3	305.0	240.0	262.4	13705
Ethyl alcohol	242.5	197.2	178.9	241.2	243.1	179.9	15495
Propyl alcohol	260	157.0	144.6	199.2	263.7	143.7	15590
Acetic acid	320	116.4	150.6	....	321.6	150.7	12502

curve of observed vapor pressures cuts the curve of calculated vapor pressures in the neighborhood of the critical temperature, the observed vapor pressure curve having, of course, the steeper trend. This is at once evident by the change from positive to negative values of the differences between the calculated and observed vapor pressures.

We would here point out the great accuracy of these measurements made by Drs. Ramsay and Young and by Dr. Young and his co-workers. The conclusion that the calculated minus the observed vapor pressure should be negative near the critical temperature was wholly theoretical on our part. That we should be able at once to verify this conclusion from the measurements when the differences were so small as to have been laid by the observers themselves on the errors of measurement (the regularity of the differences having escaped observation) speaks for itself as to their accuracy and skill. The observed and calculated vapor pressure lines are almost indistinguishable even at the critical temperature and when drawn to a large scale.

In order to show that equation 4, or the more general form equation 3, does give results in accord with Biot's formula at points considerably below the critical temperature we have published in Table 2, Jour. Phys. Chem. 9, p. 408 (1905), the values of the $\frac{\delta P}{\delta T}$ calculated from both formulas at intervals for some 50° C below the critical temperature. We have already pointed out that equation 3 itself becomes inaccurate at yet lower temperatures.

CORRECT VALUES FOR μ' NEAR THE CRITICAL TEMPERATURE.

Since equation 3 enables us to obtain in the neighborhood of the critical temperature more nearly correct values for the $\frac{\delta P}{\delta T}$ than we had been able to obtain in previous papers when working with Biot's formula we concluded to use these values and test more thoroughly the equation,

$$[9] \qquad \frac{L - E_1}{\sqrt[3]{d} - \sqrt[3]{D}} = \text{constant} = \mu'.$$

discussed in previous papers[1]. If the value of the $\frac{\delta P}{\delta T}$ from equation 3 be substituted in the thermodynamical equation 2, the values of the heat of vaporization so calculated are the same as those obtained from equation 1. Therefore using these values and substituting them in equation 9 we obtain the corrected values for the constant. The results so obtained at those points nearest the critical temperature are given in Table 2 under the heading "New". For comparison we give under heading "Old" the values that we had previously obtained for μ' at this same temperature when using the $\frac{\delta P}{\delta T}$ obtained from Biot's formula in calculating the heats of vaporization thermodynamically. Also we give, under the heading "Mean", the average value of the constant previously adopted. Agreement is not of course to be expected for the four associated substances last shown in the table. For the other substances there is little question but that the constants so obtained agree with the mean values to within the limit of experimental error except in the cases of di-isobutyl, normal heptane, normal octane, and methyl acetate. We are unable to explain the smaller values obtained from these four substances, but the proof that equation 9 does hold as near the critical temperature as it is possible for measurements to be made is now complete for ethyl oxide, di-isopropyl, isopentane, normal pontane, normal hexane, benzene, hexamethylene, fluo-benzene, carbon tetrachloride, stannic chloride, methyl formate, and ethyl formate.

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[1] **Jour. Phys. Chem., April, 1902; June, 1904; Dec., 1904.**

THE VALUE OF μ' AT THE CRITICAL TEMPERATURE.

It is possible to extend this proof quite to the critical temperature itself. Substituting in equation 9 the value of L given by the thermodynamical equation 2, and the value of $E_1 = .0_4 3183\,P\,(V - v)$, we have

$$[10] \qquad \frac{.0_4 31833\left(T\frac{\delta P}{\delta T} - P\right)\left(V - v\right)}{\sqrt[3]{d} - \sqrt[3]{D}} = \mu',$$

and obtaining the limit of this equation as V approaches v in value we have for the equation at the critical temperature, where $V = v$, the form

$$[11] \qquad .0_4 955\, V^{4/3}\left(T\frac{\delta P}{\delta T} - P\right) = \mu'.$$

As we have shown the most correct value for the $\frac{\delta P}{\delta T}$ available at this temperature is that given by equation 4 and substituting this value in the equation we get,

$$[12] \qquad \mu' = V^{1/3}\left(\frac{11.924\, T}{m} - .0_4 955\, P\, V\right).$$

This equation is the same as equation 17 of the third paper[1]. Here V, T, and P, are the critical volume, temperature, and pressure respectively, and m is the molecular weight of the substance under consideration. The equation is interesting because it gives a method for calculating the constant of molecular attraction, μ', in terms of the critical constants and the molecular weight of the substance. Since the molecular weight enters into the equation it evidently cannot be applied to associated substances. Again using the critical data, already referred to, given by Young, the values obtained from this equation are shown in Table 2 above. Except for di-isobutyl, normal heptane, normal octane, methyl acetate,

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[1] Jour. Phys. Chem., Dec., 1904.

and to a less degree for ethyl formate, the agreement with the mean values of μ' is excellent and we may therefore regard the truth of equation 9 as having been established at the critical temperature itself for fifteen of the nineteen substances under consideration. (Ethyl formate decomposes slightly at the higher temperatures which is sufficient to account for the divergence, three per cent., there observed.) We have already shown that normal heptane and normal octane give constant values for μ' in equation 9 over a range of more than 200° C in temperature. We have unpublished results showing the same to be true for methyl acetate. Diisobutyl did give a variation of several per cent. at low temperatures, a divergence that we think was sufficiently explained[1]. It would seem probable therefore that the divergences shown by these four substances at the critical temperature must be due to some change or decomposition taking place in the substance at that temperature and that equation 9 is applicable for all normal substances quite up to the critical temperature.

RATIO OF THE THEORETICAL TO THE ACTUAL CRITICAL DENSITY.

In a preceding paper[2] we showed that the molecular attraction at unit distance, μ, was equal to $c\mu'\sqrt[3]{m}$. Therefore we have from equation 12,

$$[13] \qquad \mu = c\sqrt[3]{m\mathrm{V}}\left(\frac{11.924\ \mathrm{T}}{m} - .0_4955\ \mathrm{P\,V}\right).$$

In the same paper on the assumption that the critical temperature was the point where the kinetic energy of the molecules was just balanced by the molecular attraction we derived equation 24 of that paper, viz.:

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[1] Jour Phys. Chem., 8, 595 (1904).

[2] Jour. Phys. Chem., 8, 630 (1904).

[14] $$\mu = c' \frac{T}{m} \sqrt[3]{\frac{m}{d}}.$$

where T is the critical temperature and d is the critical density. We can now combine this value of μ with the value of μ given in equation 13 and obtain,

[15] $$c' \frac{T}{m} \sqrt[3]{\frac{m}{d}} = \sqrt[3]{mV} \left(\frac{11.924\, T}{m} - .0_4955\, PV \right),$$

whence,

[16] $$\frac{PVm}{T} = \text{constant}.$$

We show the values of $\frac{PVm}{m}$ in Table 2 and it will be seen that hexamethylene and carbon tetrachloride alone (the associated substances being excepted) give a value more than three per cent. from the average value 16293.

$\frac{.0_4 16014\, Pm}{T}$ is the theoretical critical density and equation 16 is really the ratio of the theoretical, D_c, to the actual critical density, d_c, and can take the form,

[17] $$\frac{D_c}{d_c} = \text{constant}.$$

The relation in this form has been fully discussed by Dr. Young[1]. It here appears as a necessary consequence of the ideas that we have advanced though we did not foresee that such would be the case, and hence are justified in considering the deduction of this relation as further evidence that those fundamental ideas upon which this series of papers is based are correct.

It may seem unusual that we should have been able to derive two different equations for μ (equations 13 and 14) in terms of the critical constants. This is due to the fact that the critical temperature besides possessing the property that the molecular attraction just balances the kinetic energy of the molecules—the relation upon which equation 14 is based

[1] **Phil. Mag., [5], 50, 291 (1900).**

—can also be viewed as the boiling point and from this point of view permits the deduction of equation 13. We hope shortly to complete a paper applying these ideas of molecular attraction more fully to the boiling point.

We should also point out that by combining equation 11 with equation 14, we get,

$$\frac{T}{m} = cV\left(T\frac{\delta P}{\delta T} - P\right), \tag{18}$$

where c is a constant. This equation can be solved so as to give any one of the variables at the critical temperature in terms of the others and the molecular weight. It is not feasible now to further examine this equation, since the only correct values for the $\frac{\delta P}{\delta T}$ are obtained from equation 4 and this at once reduces the equation to the form of equation 16.

Dr. Young has shown that the average constant of equation 17 is $\frac{1}{3.827}$. Since the theoretical critical pressure is therefore 3.827 times the actual critical pressure it follows from the gas law and equation 5 that at the critical temperature,

$$\frac{\delta P}{\delta T} = \frac{7.654\,P}{T}. \tag{19}$$

This equation can be obtained directly from equation 18 but the constant is then unknown.

SUMMARY.

1. It is shown that the $\frac{\delta P}{\delta T}$ for a liquid (vapor) at the critical temperature is exactly twice what it would be for the same substance as a gas occupying the critical volume.

2. It is shown that Biot's formula for vapor pressure cannot be made exactly to fit the true vapor pressure curve in the immediate neighborhood of the critical temperature. When

the pressure is considered the proportional error is very small. When the $\frac{\delta P}{\delta T}$ is considered the proportional error is large, and the values obtained from Biot's formula are too small.

3. The equation, $\frac{L - E_1}{\sqrt[3]{d} - \sqrt[3]{D}} = \mu'$, where μ' is the constant of molecular attraction, is shown to be applicable with exactness in the immediate neighborhood of and at the critical temperature for fifteen out of nineteen substances considered. The equation has already been proved accurate at lower temperatures.

It is shown that the constant of molecular attraction, μ', can be calculated from the critical constants and the molecular weight.

5. The known fact that the ratio of the theoretical to the critical density is a constant for all substances is shown to follow necessarily from the fundamental ideas and equations upon which this series of papers is based.

University of North Carolina,
April 3rd, 1905.

VOL. XXI NOVEMBER, 1905 NO. 3

JOURNAL

OF THE

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JOURNAL

OF THE

ELISHA MITCHELL SCIENTIFIC SOCIETY.

NOVEMBER, 1905

VOL. XXI NO. 3

PROCEEDINGS OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY.

155TH MEETING, OCTOBER 11, 1904.

Professor William Cain, President, in the chair.

The following papers were presented:

The Construction of a Double Six—*A. Henderson.*

The Geological History of Currituck Banks—*Collier Cobb.*

A. S. WHEELER,
Recording Secretary.

156TH MEETING, NOVEMBER 8, 1904.

Professor William Cain, President, in the chair.

The following papers were presented:

Molecular Attraction—*J. E. Mills.*

Experiments on the Development of the Skeleton in Sponge Larvae—*H. V. Wilson.*

The Theories of Dyeing with Special Reference to the Constitution of Cellulose—*A. S. Wheeler.*

A. S. WHEELER,
Recording Secretary.

157TH MEETING, JANUARY 10, 1905.

Professor William Cain, President, in the chair.

The following papers were presented:

The Theory of Metal or Re-enforced Concrete Domes—*William Cain.*

Steel Hardening Metals—*J. H. Pratt.*

A. S. WHEELER,
Recording Secretary.

158TH MEETING, FEBRUARY 14, 1905.

Professor William Cain, President, in the chair.

The following papers were presented:

Mode of Inspection of the Hookworm Disease—*R. H. Whitehead.*

The Mystic Hexagram—*Archibald Henderson.*

Statistics of Cotton Manufacturing in the South—*C. L. Raper.*

A. S. WHEELER,
Recording Secretary.

159TH MEETING, MARCH 14, 1905.

Professor William Cain, president, in the chair.

The following papers were presented:

Normal Paper—*A. S. Wheeler.*

The Mutation Theory—*W. C. Coker.*

Chemical Affinity: A Method for Distinguishing Chemical Energy from Simultaneous Physical Energy Changes—*J. E. Mills.*

A. S. WHEELER,
Recording Secretary.

160TH MEETING, APRIL 11, 1905.

Professor William Cain, president, in the chair.

A motion was made and carried that the old arrangement with the North Carolina Academy of Science be changed to read as follows: The Mitchell Journal to publish minutes and abstracts of papers for the annual meeting of the North Carolina Academy of Science for the sum of fifty dollars a year and that The Journal be sent to all members of the Academy, but not to the associate members.

The following papers were presented:

The Edison Storage Cell—*J. E. Latta.*

The Organization of the Ovum—*H. V. Wilson.*

Autophytographs—*Collier Cobb.*

A. S. WHEELER,
Recording Secretary.

BUSINESS MEETING, SEPTEMBER 27, 1905.

Professor William Cain, president, in the chair.

Officers for the ensuing year were elected as follows:

President, H. V. Wilson.

Vice-President, Archibald Henderson.

Corresponding Secretary, F. P. Venable.

Recording Secretary, A. S. Wheeler.

Editorial Committee on The Journal: W. C. Coker, Chairman; Archibald Henderson, J. E. Latta.

A. S. WHEELER,
Recording Secretary.

SOME PROBLEMS IN THE CELLULOSE FIELD.*

BY ALVIN S. WHEELER.

Professor of Chemistry, University of North Carolina.

The vegetable cell is a laboratory in which are carried out a most remarkable series of chemical reactions. As we contemplate the immense number of organic compounds of all degrees of compounds which are formed within the walls of the plant cell we are convinced that this is the chemical laboratory par excellence. Two features impress us particularly: first, the silence in which the operations are carried on; second, the narrow range of medium temperatures required. Notwithstanding this apparent simplicity of conditions the products are of the most various kind. Some of these man is able to synthesize in his own crude way; others are still the secrets of nature. It is utterly impossible for man to prepare certain naturally occurring compounds except at a temperature which would burn the plant tissue. We are led to wonder whether forces exist of which we are unacquainted or whether we are merely unable to control the forces already familiar to us. It would be difficult to say which supposition is the more probable. It will be granted that investigation into the activities of the cell is of profound importance. In fact it has been said that "it is in the plant cell where synthetical operations are predominant that we have to look for the foundations of the 'new chemistry' which may be expressed broadly as the relation of matter to life."

Among the products which result from the activities of the cell is cellulose, an essential constituent of all plant tissue. Plant physiologists have been accustomed to identify cellulose

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*Reprinted from The Chemical Engineer, Vol. II., No. 3, July. 1905.

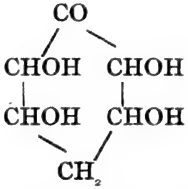
with the cell wall, but modern investigation has demonstrated the error of this belief by showing that the ultimate products of hydrolysis of different cell walls are not the same. Cotton, for instance, yields dextrose; the cell walls of the seeds of Lupinus lutevs, and many other plants give galactose, while the seeds of the cereals and leguminous plants yield arabinose and xylose. It is clear that cell walls are not of uniform composition. How they actually differ has not yet been determined, their differentiation being an extremely difficult problem. The name cellulose does not apply to a single individual, existing in only one form, like ethyl alcohol. Analyses of various bodies regarded as cellulose give figures leading to the empirical formula $(C_6H_{10}O_5)n$ in which the carbon percentage is 44.2 and the hydrogen is 6.3. The highest percentage of cellulose is obtained from cotton, the yield being approximately ninety per cent. Most of the remainder is water, and there are very small amounts of ash and complex organic compounds. Flax, hemp and ramie also give large yields of cellulose. Again, cellulose is used to designate combinations of the body already mentioned with highly complex radicals of unknown constitution. These are compound celluloses and are more specifically termed lignocelluloses, muco-celluloses, pectocelluloses, adipocelluloses and cutocelluloses. Some progress has been made in the constitutional study of these compounds, more especially the lignocelluloses. Cross and Bevan have studied the lignocellulose of jute, selecting this form because it seemed likely to be the simplest representative since jute matures in one season. They recognize the following general constituents: (a) α-cellulose, an oxidized cellulose; (b) β-cellulose, a less resistant form and yielding a large amount of furfural on hydrolysis; (c) lignone, a radical containing the carbonyl group and about one-third of which is of the benzeneoid type.

The difficulties surrounding the experimental study of the celluloses are very great. Their insolubility in the ordinary solvents precludes purification in the usual way and renders impossible any molecular weight determinations by the freezing or boiling point methods. They dissolve in a concentrated aqueous solution of zinc chloride and in cuprammonium, forming colloidal solutions from which they may be precipitated as gelatinous hydrates. The fact that they are colloids presents one reason why chemists have not been more attracted to their study. Colloids have been very unmanageable, but it is very noticeable that an increased amount of work is being done upon them. In the year 1890 only three communications upon colloids appeared, while in 1900 there were twenty-three. A brief statement of their properties is sufficient to show their unattractiveness. They possess little affinity, do not crystallize, dissolve to an indefinite degree in a very limited number of solvents, are filtered by animal membranes and form gelatinous precipitates. According to one view which is held by many we have in the colloidal solution not a solution at all, but a suspension of very finely divided particles which are much larger than simple molecules. In view of their precipitation by electrolytes their study is being prosecuted by electro-chemists and, although more attention is being paid to the inorganic colloids, the whole subject is undergoing development. As new light is obtained, a deeper insight into the character of the celluloses will necessarily follow. It will help to make possible a scientific classification, something which is lacking at present.

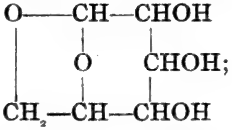
The formation of the celluloses is one of the most interesting problems connected with them and a very fundamental, one, too. What is the antecedent of cellulose? Durin has observed the formation in beet juice of a white insoluble substance, possessing the characteristic of cellulose. If this substance is transferred to a pure cane sugar solution, more of it is formed. These observations point to cane sugar as the predecessor of cellulose. The more elaborate investigations of Brown and Morris point more clearly to the same conclusion. Their study of foliage leaves persuaded them that starch is not the raw material out of which cellulose is built up, but that is rather a reserve material to be drawn upon in case of cell starvation, that is, when all the cane sugar has been translocated as dextrose and levulese. The problem can not be regarded as settled and further work in this direction is highly desirable.

As already stated, the simple celluloses are represented by the empirical formula $(C_6H_{10}O_5)n$, the letter n standing for a number which is wholly problematical, although Bumcke and Wolffenstein have suggested 12. As for a constitutional formula this has yet to be worked out. How much progress has been made and what remains to be done? The great stability of cellulose, made familiar by its almost universal use as a filtering medium, has precluded in the minds of many of us a realization of the chemical activity which it really possesses. Its attraction for water is very strong, cotton cellulose retaining from six to twelve per cent. in the air-dried condition, and if this water is driven off, it will be reabsorbed on exposure to the atmosphere. This hygroscopic property bears an undetermined relation to the presence of hydroxyl groups because it decreases as the number of hydroxyl groups is diminished by substitution of acid radicals. Since the tetracetate seems to be the highest normal acetate, it is probable that there are four hydroxyl groups. The other oxygen atom is combined with carbon to form a carbonyl group, although this is not in the usual reactive condition. In the easily derived hydro- and oxy-celluloses it appears at once in natural character of a reducing agent. The large proportion of acetic acid obtained when cellulose is fused with alkaline hydroxides indicates the presence of $CO\text{-}CH_2$ groups. Its resistance to the action of halogens and alkalies shows it to be a saturated compound. Owing to the similarity of the empirical formula of cellulose and starch and to their association in the processes of nature, it has been customary to regard them as very closely related in constitution. However, there is undoubtedly a fundamental difference between them. Vignon has subjected purified cotton and starch to hydrolysis with dilute hydrochloric acid at 100°. The percentage yields of reducing products equal to dextrose were as follows: cotton, 3.29; starch, 98.6. Fenton and Gostling have brought out another striking behavior. Cotton cellulose is acted upon by dry hydrobromic acid in ethereal solution producing w-Brommethylfurfural, a 33 per cent. yield being obtained. Under the same treatment potato starch yielded only 3.7 per cent. The belief is growing that cellulose does not belong to the straight chain compounds with the sugar and starches, but is instead a ring compound. Three formulae have been proposed for the unit group, $C_6H_{10}O_5$, as follows:

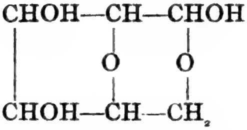
Cross and Bevan's,



Vignon's,

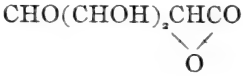


Green's,



Any general theory of dyeing must take into account the constitution of cellulose. The three theories which have been held are (a) the mechanical, (b) the solid solution, and (c) the chemical. In view of the diverse chemical character of the three most important textile materials, silk, wool and cotton, it seems improbable that one theory will ever occupy the field to the exclusion of the other two. There are no reasons a priori for not combining the three by selecting what truth there may be in each one. The attempts to hold to one theory have been attended with serious difficulties. As for cellulose (cotton and linen fabrics) its nature as a chemical compound comes into play in certain dyeing processes. It behaves as a weak acid and if this acid character is increased by conversion into oxycellulose, it exhibits an increased affinity for basic dyes. On the other hand, Vignon has caused cotton by treatment with ammonia under various conditions to take up as much as 2.86 per cent. N which is not extracted by dilute hydrochloric acid and now, possessing basic properties, it will take an acid dye from an acid bath. These reactions seem to be cases of simple salt formation. As for the solid solution theory Witt regards substantive dyeing as a case of one solid dissolving another. The dye, being more soluble in the fibre than in the water, is extracted therefrom by the fibre and in the fibre the dye exhibits the same characteristics which it shows in aqueous solution. According to this view the chemical nature of the textile is of no consequence except as it affects its solvent capacity. The behavior of cellulose with certain dyes does not seem to militate against this view. The general question is constantly under investigation.

Although cellulose is distinguished by its permanence, it is attacked by a great variety of oxidizing agents. The product, called oxycellulose, is not uniform in character and experimenters seldom agree in their analytical data. Bumcke and Wolffenstein recently discarded the term oxycellulose and re-opened the whole question. The action of hydrogen peroxide upon filter paper was studied. They came to the conclusion that cellulose can not undergo simple oxidation without hydrolysis. They substitute the name hydracellulose for oxycellulose, this name indicating the hydrolytic production and aldehydic properties of the product. It bears the same relation to cellulose as glucose to cane sugar. Tollens has also recently investigated the oxycellulose and proposes the name celloxin for a body with the formula $C_8H_6O_6$, or $C_6H_{10}O_6$, believing that the oxycelluloses are varying mixtures of cellulose with celloxin. Attempts to isolate celloxin have been unsuccessful. Vignon suggests that oxycellulose consists of three molecules of cellulose associated with the group



$$\mathrm{CHO(CHOH)_2\overset{}{CH}CO} \quad \text{(CH and CO joined through O)}$$

which is at once an aldehyde, an alcohol and a lactone. The unsettled state of this part of the field is apparent.

The fermentation of cellulose, although an important question, has been studied by a few investigators only, notably Hoppe-Seyler, Tappeiner, Omelianski and Van Senus. Insufficient work has been done upon pure cellulose and I have undertaken this phase of the investigation. Van Tieghen states that the cellulose ferment corresponds in properties with "amylobacter," a bacterium described by him, and it has been commonly asserted since that this was the cellulose ferment. Van Senus regards this as extremely doubtful, since these bacteria do not attack cellulose suspended in a meat extract solution. The fermentation is anaerobic and the products of decomposition are hydrogen, carbon dioxide, methane, acetic and butyric acids, the proportions varying with the conditions. If the fermentation can be carried out so that an intermediate product like alcohol is obtained, a discovery of tremendous importance will have been made. The subject of fermentation is also important in its relation to digestion not only in the human species but more especially in herbivorous animals.

Through the decomposition of cellulose by chemical reagents there are obtained oxalic acid, alcohol and sugar, according to the conditions employed. Classen has gotten out a number of patents for the production of sugar (dextrose) from wood and he makes the startling claim that sulphuric acid converts all of the cellulose in wood into sugar. When we consider the vast waste of cellulose in the form of sawdust (acres of it about a single saw mill) the possibilities of a new source of sugar (and from that, alcohol) are extremely interesting.

Cellulose is acquiring a greater and greater importance in the arts and manufactures. Its use as a paper stock and as a raw material for clothing place it in the front rank of industrial products. Some of its derivatives also find extensive application, the nitro-celluloses for explosives, artificial silk and celluloid, and the thiocarbonate for artificial silk. The tetracetate has been found to possess insulating powers superior to gutta-percha and it is now a commercial product. If a solution of the acetate is allowed to evaporate a film of great tenacity is obtained which may be used in photography and for laquering metals. An acetate may also be obtained in the form of a powder, soluble in chloroform and nitrobenzol. This is used for preparing substances resembling celluloid and as a substitute for collodion. Its advantages lie in the fact that it is odorless and is not inflammable. Two problems which have not been seriously attacked are the conductivity of pure cellulose and the use of cellulose as a membrane in osmotic work. Many other questions of varying degrees of importance might be mentioned.

In concluding this brief survey I wish to express my agreement with the idea now often expressed that the demarcation line between the scientific and the practical has hitherto been too sharply drawn. Professor Jordan recently said: "It is often a temptation to distinguish radically between pure science and applied science and to look upon the latter as unworthy the attention of the philosophically minded. True science can admit of no such distinction," and President Jordan says, "Applied science can not be separated from pure science, for pure science may develop at any quarter the greatest and most unexpected economic values, while, on the other hand, the applications of knowledge must await the acquisition of knowledge before any high achievement in any quarter can be reached. * * * Whatever is true is likely sometime to prove useful and all error is likely sometimes to prove disastrous."

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EXPERIMENTS ON THE PRODUCTION OF CRUDE TURPENTINE BY THE LONGLEAF PINE.

BY CHAS. H. HERTY, PH.D.

With the hope of improving the method of distillation commonly practiced in the production of spirits of turpentine from the crude resin of the Longleaf Pine, the writer, at that time connected with the University of Georgia, began a systematic study of conditions throughout the turpentine belt. Information was gathered from publications of the U. S. Department of Agriculture and from correspondence with leading men in the naval stores industry, railroad officials and others.

It soon became apparent that the industry, which had started on a rather small scale in eastern North Carolina, had grown to large proportions, affording employment to thousands of laborers and furnishing the world with at least nine-tenths of the spirits of turpentine and rosin used in manufactures. It also became evident that during this period of growth the forests of North Carolina and South Carolina had been almost completely exhausted, while those of Georgia were being rapidly destroyed. Throughout the territory methods of operation were absolutely uniform. A visit to different sections showed at once the explanation of the complete destruction of the forests in the Carolinas, for in addition to the removal of timber by the lumbermen, fires and storms following in the wake of the turpentine operator had completed the destruction. It needed no close observation to determine at once that the chief cause of this destructive action by fires and storms was the "box", a large and deep hole cut into the trunk of the tree at its base to receive the resin which exudes during the spring and summer months from the freshly scarified trunk above.

In the cutting of the "box" or "boxes" in the base of the tree its trunk is partly severed and in storms splits off at the top of the box, breaking usually three or four feet higher.

Again, the turpentine belt is characterized by a complete ground covering of "wire grass" whose exposed blades die during winter and are annually burned off in the early spring months to furnish better grazing for cattle. So long as turpentine operations are active, these ground fires do not damage the trees, for during the winter the laborers remove with hoes all wire grass and fallen straw a safe distance from each tree; but when the forest is abandoned, this precaution is no longer taken and with the next fire the resin which has gradually accumulated in the old "box" takes fire, the heat melts the resin on the scarified surface above which, flowing into the box, adds fuel to the flames until the tree falls; or if the case is not so extreme, until the tree is weakened to such an extent that it can no longer resist the attacks of injurious insects which soon kill it.

The evident loss from this factor was so much greater than from imperfections in the method of distillation that common sense prompted that immediate efforts be diverted from the matter of distillation to that of a practical device for collecting the resin which would render unnecessary the cutting of the "box". Many evidences were found of unsuccessful efforts to introduce a form of a cup system, some of these being identical with the cup system used in the turpentine forests of France since 1860. But none had found any permanent place in the industry.

With a simple apparatus somewhat like the French, consisting of a cup and two metallic troughs, preliminary experiments were begun during the summer vacation of 1901 at Statesboro, Ga. The metallic troughs or gutters, consisting of two inch strips of sheet galvanized iron, bent along the middle to form a trough, are inserted in inclined shallow cuts across flattened surfaces of the tree and serve to lead the resin to a central point. One of the gutters is slightly higher than the other, delivering its resin into the lower gutter, from the end of which all the resin drips into the cup suspended on a nail just below. Such an apparatus can at the end of each season be easily raised to a point near the scarification surface. With this apparatus tests were made primarily of its practicability and effectiveness. Further, the quality of the resin exuding from the trees in successive years of operation was determined. Under the "box" system the resin of the second, third and fourth years of operation shows gradually increasing coloration and the rosin left after distillation of the volatile spirits of turpentine is a deeper red and less valuable. With the cup and gutters placed near the freshly scarified surface, it was proved that the quality of the resin so far as concerns color is as good in the fourth as in the first year, the color of the resin from the old "boxes" being due to absorption of the highly colored oxidized resin on the long surface above the "box". Quantitative experiments were made upon the loss of resin which falls outside of the "box", due to trunks not perpendicular, and of the loss of volatile spirits of turpentine during the long flow to the "box". It was also shown that different portions of the circumference of a tree, in many cases, vary greatly in ability to produce resin, and that the underside of a leaning tree is much more productive than the upper side. The daily rate of flow after scarification was studied and it was found that in general, sixty per cent. of the flow takes place during the first period of twenty-four hours, twenty-five during the second and after seven days, the flow practically ceases. Numerous other studies were projected and some were partly carried out, but the summer vacation being ended, it was necessary to discontinue the work in the field.

The interest of the U. S. Bureau of Forestry was aroused by these preliminary experiments and by the promise of practicability in the simple apparatus used. This led the writer during the following winter to accept a commission from the Bureau to undertake field experiments on a commercial scale to test further the usefulness of the appartus in the hands of the average turpentine laborer, and to determine the important question of whether or not the cutting of the box decreases the productive power of the tree.

Crude turpentine (resin) is a pathological product, resulting from the wound given the tree in scarification. It is necessary to wound the tree to get the flow of resin, but the cutting of the "box" is an unnecessary and intense wound and it seemed reasonable to expect that in comparative experiments trees which are not "boxed" would, with all other conditions equal, show an increased yield.

These field tests were carried out at Ocilla, Ga., on the place of Messrs. Powell, Bullard & Co. About twenty-five thousand trees were used during the first year. From one-half of these the resin was collected in the usual "box"; on the other half cups and gutters were placed. Four distinct sets of experiments were made corresponding to first, second third and fourth years of operation, five thousand cups and five thousand boxes in each set. Every precaution was taken to insure uniformity of conditions between the two halves of each set, or "crop" as designated in turpentine operating. Careful record was kept of the yield from all of the eight half "crops", each being separately distilled and the products sold separately. The results of the year's tests were published by the Bureau of Forestry as Bulletin No. 40, entitled "A New System of Turpentine Orcharding".

After the first year, the experiments were continued only on one of the four sets, that designated "first" above, for only in this set did full conditions for comparative results obtain, one-half of the trees in this set never having been "boxed", while in the other three sets, all of the trees had been boxed in previous years of operation.

After conducting the tests three years, the experiments were discontinued and the results published by the Bureau of Forestry as Circular No. 34 entitled "Practical Results of the Cup and Gutter System of Turpentining". The summary of these results shows the total value of the products (spirits of turpentine and rosin) from three years of operation to have been from

the cupped half-crop	$2,688.55
the boxed half-crop	2,046.53
Gain from cupped half-crop	$ 642.02

an increase of about 32 per cent over the "box" system.

The results of the first year of operation of these two half-crops, during which time conditions were identical in each except that in one half crop "boxes" had been cut in the trees, showed an increased yield from the unboxed trees of 23.5 per cent., thus confirming the hypothesis that the cutting of the box decreased the productive power of the tree.

The publication of these results has resulted in the commercial introduction of the system on a large scale, and in many cases the results obtained with the apparatus have exceeded those obtained in the experimental tests.

But the introduction of the cup system cannot of itself save the forests of Longleaf Pine from destruction. If too great a proportion of the circumference of the tree be removed in scarification, or "chipping" as it is termed, the tree will die whether a "box" has been cut or a cup hung. Further experiments have, therefore, been begun by the Bureau of Forestry to determine to what extent the wound given in "chipping" can be decreased in width, height and depth without decreasing the production. It is possible that by moderate reduction the production may even be increased. These experiments are now in progress.

A MEMOIR ON THE TWENTY-SEVEN LINES UPON A CUBIC SURFACE.

PART II.

ARCHIBALD HENDERSON, PH.D.

CHAPTER II.

THE CONFIGURATION OF THE DOUBLE-SIX. AUXILIARY THEOREMS.

§5. *The Double-Six Notation.*

Let us write down, in Salmon's notation, two systems of non-intersecting lines

$$\begin{matrix} ab, & cd, & ef, & (ad \cdot cf \cdot eb)_1, & (ad \cdot cf \cdot eb)_2, & (ad \cdot cf \cdot eb)_3 \\ cf, & eb, & ad, & (ab \cdot cd \cdot ef)_1, & (ab \cdot cd \cdot ef)_2, & (ab \cdot cd \cdot ef)_3. \end{matrix}$$

In this scheme, according to former postulation (§4), each line of one system does not intersect the line of the other system, which is written in the same vertical line, but does intersect the five other lines of the second system.

The configuration was first observed by Schläfli* and was given by him the name it has since borne—a "double-six". The concept of the double-six lies at the very basis of the study of the lines upon a cubic surface and the notation

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*"An attempt to determine the twenty-seven lines upon a surface of the third order, and to divide such surfaces into species in reference to the reality of the lines upon the surface", Quarterly Journal of Math (1858), vol. II, pp. 55–65, 110–120.

derived therefrom is the most simple and convenient that has yet been discovered for the 27 lines and 45 triple tangent planes.

NOTATION. Starting with the double-six, written

$$\begin{matrix} a_1, & a_2, & a_3, & a_4, & a_5, & a_6 \\ b_1, & b_2, & b_3, & b_4, & b_5, & b_6 \end{matrix}$$

we are enabled to express the complex and diversified symmetry of the 27 lines and 45 triple tangent planes in unique and simple form.

Returning to the double-six, written in Salmon's notation, it appears that the lines *ab*, *cb*, and *eb* lie in the same plane and are the only three of the 27 lines that lie in the plane *b*. In like manner *cb*, *cd*, and *cf* all lie in the plane *c* and hence the line that lies in the plane of *ab* and *eb* is identical with the line that lies in the plane of *cd* and *cf*, viz., the line *cb*.

In the new notation, we shall call the third line in the plane of a_1, and b_2 which intersect, the line c_{12} and the triangle so formed shall be designated by 12. As has been shown above, the side c_{12} forms with a_2 and b_1 a triangle, designated 21. Hence we have 15 $(\equiv {}_6c_2)$ lines c, each of which intersects only those four lines a, b the suffixes of which belong to the pair of numbers forming the suffix of c. For suppose c_{12} should intersect any other line, say a_3, of the eight lines a_3, a_4, a_5, a_6; b_3, b_4, b_5, b_6. Then c_{12} intersecting a_1, b_1, a_2 and b_2 already, $c_{12}\ a_3\ b_1$ and $c_{12}\ a_3\ b_2$ form two triangles, and since they have two lines in common, their planes are identical and consequently b_1 intersects b_2, contrary to hypothesis.

Any two *c's*, the suffixes of which have a number in common, do not intersect. For suppose c_{12}, c_{13} intersect; they form a plane in which a_1 and b_1 lie and therefore a_1 meets b_1, contrary to hypothesis. It may also be shown that any two *c's*, the suffixes of which have no number in common, do intersect.

These facts may be briefly put as follows:

$$\left.\begin{array}{l} c_{ij}\text{ intersects } a_i,\ b_j;\ a_j,\ b_i \\ c_{ij}\text{ intersects } c_{kl} \\ c_{ij}\text{ does not intersect } c_{ik} \\ \qquad c_{ij} \equiv c_{ji} \\ \quad \Delta_{ij}\text{ is not equal to } \Delta_{ji} \end{array}\right\} \begin{array}{c} (i,\ j,\ k,\ l = 1,\ 2\ .\ .\ .\ 6) \\ i,\ j,\ k,\ l,\text{ all distinct} \end{array}$$

We see then that there are triangles of the form c_{12}, c_{34}, c_{56}, which may be briefly represented by 12 · 34 · 56. Hence there are thirty (${}_6P_2$) triangles of the type 12 and fifteen of the type 12 · 34 · 56. The latter arises from the fact that, if we fix our attention upon 12, the other two sets may be written in only three ways.

§6. *History of the Theorem.*

In 1858 Schläfli (*l. c*) proved the double-six theorem incidentally in connection with his investigations on the 27 lines on the cubic surface. He enunciated the theorem in the following form:—

Given five lines a, b, c, d, e, which meet the same straight line X: then may any four of the five lines be intersected by another line. Suppose that A, B, C, D, E are the other lines intersecting (b, c, d, c), (c, d, e, a), (d, e, a, b,), (e, a, b, c,) and (a, b, c, d) respectively. Then A, B, C, D, E will all be met by one other straight line x.

The double-six in this case is written

$$\begin{pmatrix} a, & b, & c, & d, & e, & x \\ A, & B, & C, & D, & E, & X \end{pmatrix}$$

Schläfli then proposes the question—"Is there, for this elementary theorem, a demonstration more simple than the one derived from the theory of cubic forms?"

Sylvester* states that the theorem admits of very simple

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*Note sur les 27 droites d'une surface du 3^e degré," Comptes Rendus, vol. LII (1861) pp. 977–980.

geometrical proof but he did not give the proof. Salmon* has given a method for geometrically constructing a double-six but I do not understand it to be a PROOF of the theorem, independent of the cubic surface.

In 1868 Cayley† gave a proof of the theorem from purely static considerations, making use of theorems on six lines in involution. Again in 1870 Cayley‡ verified the theorem, using this time his method of the six co-ordinates of a line. Kasner|| has recently given a proof by using the six co-ordinates of a line.

The method I have adopted in the following is independent of the theory of cubic surfaces.

[NOTE. This proof and a model of the configuration constructed in Nov. 1902, were presented by me before the Chicago Section of the Am. Math. Society on April 11th, 1903. I had not at that time seen Kasner's article in the April, 1903, number of the American Journal, an article having points of contact with mine.]

§7. *Proof of the Double-Six Theorem.*

Representing the double-six in the Schläfli-Cayley notation

$$\begin{pmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 1' & 2' & 3' & 4' & 5' & 6' \end{pmatrix}$$

it is seen that these 12 lines have the thirty intersections $P_{ij'}$,

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***Geometry of 3 Divisions, 4th edition, p. 500.**

†"A 'Smith's Prize' Paper; Solutions", Coll. Math Papers, vol. VIII (1868) pp. 430–431.

‡"On the Double-Sixers of a Cubic Surface", Coll. Math. Papers, vol. VII., pp. 316–330; Quarterly Journal of Mathematics, vol. X, (1870) 58–71.

||"The Double-Six Configuration Connected with the Cubic Surface, and a Related Group of Cremona Transformations", American Journal of Mathematics vol. XXV, No. 2 (1903), pp. 107–122.

	1	2	3	4	5	6
1′		•	•	•	•	•
2′	•		•	•	•	•
3′	•	•		•	•	•
4′	•	•	•		•	•
5′	•	•	•	•		•
6′	•	•	•	•	•	

and determine thirty planes $\Pi_{ij'}$, (formed by the lines i and j').

Using quadriplanar co-ordinates, I choose for the lines 1′, 3′, 4′, 5′, 6′ the following equations:

$$\begin{array}{ll} 1' : & \delta\delta' Cx + \delta\delta' Az - (\alpha'\gamma'\delta - \alpha\gamma\delta')w = 0, \ \ y = 0 \\ 3' : & \gamma\gamma' Dy - (\beta'\gamma\delta' - \mathrm{K}\beta\gamma'\delta)z + \gamma\gamma' Bw = 0, \ \ x = 0 \\ 4' : & z = 0, \ \ w = 0 \\ 5' : & \delta' x - \alpha' w = 0, \ \ \gamma' y - \beta' z = 0 \\ 6' : & \delta x - \alpha w = 0. \ \ \gamma y - \beta z = 0 \end{array}$$

where we set

$$A,\ B,\ C,\ D \equiv (\alpha' - \mathrm{K}\alpha),\ (\beta' - K\beta),\ (\gamma' - K\gamma),\ (\delta' - K\delta)$$

respectively.

These five lines have a common tractor* since the determinant

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*Cayley uses the word 'tractor' to denote a line which meets any given lines.

$$\Delta_5 = \begin{vmatrix} 0, & (12), & (13), & (14), & (15) \\ (21), & 0, & (23), & (24), & (25) \\ (31), & (32), & 0, & (34), & (35) \\ (41), & (42), & (43), & 0, & (45) \\ (51), & (52), & (53), & (54), & 0 \end{vmatrix} \equiv 0$$

this being the condition* that any five lines 1, 2, 3, 4, 5 say, have a common tractor, where the equations of lines i and j are

$$\left.\begin{array}{l} a_i x + b_i y + c_i z + d_i w = 0 \\ \alpha_i x + \beta_i y + \gamma_i z + \delta_i w = 0 \end{array}\right\} \ldots\ldots\ldots\ldots (i)$$

and

$$\left.\begin{array}{l} a_j x + b_j y + c_j z + d_j w = 0 \\ \alpha_j x + \beta_j y + \gamma_j z + \delta_j w = 0 \end{array}\right\} \ldots\ldots\ldots\ldots (j)$$

respectively, and we understand by (ij) the determinant

$$\begin{vmatrix} a_i, & b_i, & c_i, & d_i \\ \alpha_i, & \beta_i, & \gamma_i, & \delta_i \\ a_j, & b_j, & c_j, & d_j \\ \alpha_j, & \beta_j, & \gamma_j, & \delta_j \end{vmatrix}$$

The fine lines 1′, 3′, 4′, 5′, 6′ constituting the co-tractorial quintuple do not mutually intersect, since in forming the determinants (ij), none of them are found to vanish. A possible difficulty arises from the fact that the hyperboloid through any three of these five collinear lines might touch a fourth, that is to say that certain four of the lines might have a double tractor.† That such is not the case appears in the sequel.

Determining now the common tractor, 2, of these five lines, we find it to have the equations

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*Sylvester, "Note sur l'involution de six lignes dans l'espace", Comptes Rendus, vol. LII (1861), pp. 815–817.

†Cayley, "On the Six Co-ordinates of a Line". Trans. Camb. Phil. Soc., vol. XI, part II (1869) pp. 290–323.

$$2: \quad \left\{ \begin{array}{l} \gamma' B\,(\delta' x - \alpha' w) - \delta' A\,(\gamma' y - \beta' z) = 0 \\ \gamma B\,(\delta x - \alpha w) - \delta A\,(\gamma y - \beta z) = 0 \end{array} \right.$$

Now, in general, four given lines have a pair of tractors. Since the five lines 1, 3′, 4′, 5′, 6 already have a single tractor 2, they have, in sets of four, five more tractors, thus:—the lines 1, 3, 4, 5, 6 are tractors of the sets (3′, 4′, 5′, 6′), (1′, 4′, 5′, 6′), (1′, 3′, 5′, 6′), (1′, 3′, 4′, 6′), (1′, 3′, 4′, 5′) respectively.

Let us proceed to determine the equations of the five lines 1, 3, 4, 5, 6. Recalling the values of A, B, C and D above, it is obvious by inspection that the equations of lines 1 and 3, meeting the quadruples (3′, 4′, 5′, 6′) and (1′, 4′, 5′, 6′) respectively, are

$$1: \quad x = 0, \ w = 0$$

$$3: \quad y = 0, \ z = 0.$$

The equations of line 4, since it meets the lines 5′ and 6′, are of the form

$$\left. \begin{array}{l} \dfrac{x}{\alpha'} - \lambda \dfrac{y}{\beta'} + \lambda \dfrac{z}{\gamma'} - \dfrac{w}{\delta'} = 0 \\[2ex] \dfrac{x}{\alpha} - \lambda \dfrac{y}{\beta} + \mu \dfrac{z}{\lambda} - \dfrac{w}{\delta} = 0 \end{array} \right\}$$

The conditions that this line meet the line 1′, written in the form

$$\left(\frac{x}{\alpha'} + \frac{z}{\gamma'} - \frac{w}{\delta'} \right) \frac{1}{\alpha\gamma} - k \left(\frac{x}{\alpha} + \frac{z}{\gamma} - \frac{w}{\delta} \right) \frac{1}{\alpha'\gamma'} = 0, \ y = 0$$

are given by

$$\lambda = 1, \quad \mu = 1.$$

Then the line 4 has the equations

$$4: \quad \left\{\begin{array}{l} \dfrac{x}{\alpha}-\dfrac{y}{\beta}+\dfrac{z}{\gamma}-\dfrac{w}{\delta}=0, \\[2ex] \dfrac{x}{\alpha'}-\dfrac{y}{\beta'}+\dfrac{z}{\gamma'}-\dfrac{w}{\delta'}=0 \end{array}\right\}$$

and we see by inspection that this line meets the line 3′ when we write its equations in the form

$$3': \quad \left(-\frac{y}{\beta'}+\frac{z}{\gamma'}-\frac{w}{\delta'}\right)\frac{1}{\beta\delta}-k\left(-\frac{y}{\beta}+\frac{z}{\gamma}-\frac{w}{\delta}\right)\frac{1}{\beta'\delta'}=0,$$

$$x=0.$$

Line 5, since it meets the lines 4′ and 6′, has equations of the form

$$\left.\begin{array}{c} z-\lambda w=0 \\[2ex] \left(\dfrac{x}{\alpha}-\dfrac{w}{\delta}\right)-\mu\left(\dfrac{y}{\beta}-\dfrac{z}{\gamma}\right)=0 \end{array}\right\}$$

Meeting line 3′ (see form last written), it is necessary to identify the equations

$$-\frac{\mu}{\beta}y+\frac{\mu}{\gamma}z-\frac{w}{\delta}=0$$

$$-\frac{1}{\delta}\left(\frac{\delta'-k\delta}{\beta'-k\beta}\right)y+\frac{(\gamma\beta'\delta'-k\gamma'\beta\delta)}{\gamma\gamma'\delta(\beta'-k\beta)}z-\frac{w}{\delta}=0$$

wherefore

$$\mu=\frac{\beta}{\delta}\left(\frac{\delta'-k\delta}{\beta'-k\beta}\right)=\frac{1}{\gamma'\delta}\,\frac{(\gamma\beta'\delta'-k\gamma'\beta\delta)}{\beta'-k\beta}$$

giving $\gamma':\gamma=\beta':\beta$

for which
$$\mu = \frac{\gamma}{\delta}\left(\frac{\delta' - k\delta}{\gamma' - k\gamma}\right)$$

and accordingly

$$\frac{\delta}{\gamma}\left(\frac{\gamma' - k\gamma}{\delta' - k\delta}\right)\left(\frac{x}{a} - \frac{w}{\delta}\right) - \left(\frac{y}{\beta} - \frac{z}{\gamma}\right) = 0$$

Applying similar reasoning to the equation

$$z - \lambda w = 0$$

with respect to the lines 1′ and 3′, we finally obtain

$$\lambda = \frac{\gamma'}{\delta'}.$$

Then the equations of line 5 are

$$5: \quad \begin{cases} \delta' z - \gamma' w = 0 \\ \beta C(\delta x - a w) - a D(\gamma y - \beta z) = 0. \end{cases}$$

Determining in a precisely similar fashion the equations of line 6, we find

$$6: \quad \begin{cases} \delta z - \gamma w = 0 \\ \beta' C(\delta' x - a' w) - a' D(\gamma' y - \beta' z) = 0 \end{cases}$$

It remains to show that the five lines 1, 3, 4, 5, 6 **have a** common tractor (in other words are collinear).

Writing out the various determinants (ij) and **substituting** in the formula for Δ_5, we obtain (after reduction)

$$\Delta_5 \equiv 0$$

and hence these five lines have a common tractor (but are ***not*** mutually intersecting, since no $(ij) = 0$).

Determining now the equations of the line, called 2′, which meets these five lines, we find

$$2' : \quad \begin{cases} (\alpha\beta' - \alpha'\beta)\delta\delta' Cx + (\gamma\delta' - \gamma'\delta)\alpha\alpha' Bw = 0 \\ (\alpha\beta' - \alpha'\beta)\,\gamma\gamma' Dy + (\gamma\delta' - \gamma'\delta)\beta\beta' Az = 0 \end{cases}$$

Hence we reach the following conclusion, which is Schläfli's theorem:—

The five lines determined from five co-tractorial lines by choosing the remaining tractor in each set of four of the latter lines, are themselves co-tractorial.

In the above proof, the complete set of lines was derived from the five co-tractorial lines 1′, 3′, 4′, 5′, 6′, but it is immaterial from which five of the primed or unprimed lines we start. Moreover the relation between the sets 1′, 3′, 4′, 5′, 6′ and 1, 3, 4, 5, 6 is a reversible one—the lines of one set are the tractors of the other set by fours and *vice versa.*

§8. *Anharmonic Ratios.*

Let us next find the co-ordinates of the points of intersection of the lines 2′, 3′, 4′, 5′, 6′ with the line 1. Determining these in the usual way and writing down also the co-ordinates of the vertex C of the fundamental tetrahedron $ABCD$, we tabulate them as follows;—

$P_{12'}$:	0	$\beta\beta'(\gamma'\delta - \gamma\delta')A$	$\gamma\gamma'(\alpha\beta' - \alpha'\beta)D$	0
$P_{13'}$:	0	$\beta'\delta'\gamma - K\beta\delta\gamma'$	$\gamma\gamma' D$	0
$P_{14'}$:	0	1	0	0
$P_{15'}$:	0	β'	γ'	0
$P_{16'}$:	0	β	γ	0
C :	0	0	1	0

The anharmonic ratio of the four collinear points $P_{12'}$, $P_{13'}$, $P_{15'}$ $P_{16'}$ is identical with the anharmonic ratio of the four parameters

$$\frac{\gamma\gamma'(\alpha\beta'-\alpha'\beta)D}{\beta\beta'(\gamma'\delta-\gamma\delta')A},\quad \frac{\gamma\gamma' D}{\beta'\delta'\gamma-K\beta\delta\gamma'},\quad \frac{\gamma'}{\beta'},\quad \frac{\gamma}{\beta}.$$

Calculating the value $\frac{\lambda_3-\lambda_1}{\lambda_3-\lambda_2}\div\frac{\lambda_4-\lambda_1}{\lambda_4-\gamma_2}$ of the anharmonic ratio of these four parameters numbered in the order in which they are written, we find

$$(P_{12'}, P_{13'}, P_{15'}, P_{16'}) = \frac{\beta'\delta'}{K\beta\delta}\left\{\frac{\beta(\gamma'\delta-\gamma\delta')A-\gamma(\alpha\beta'-\alpha'\beta)D}{\beta'(\gamma'\delta-\gamma\delta')A-\gamma'(\alpha\beta'-\alpha'\beta)D}\right\}.$$

Let us now determine the co-ordinates of the points of intersection of the lines 1, 2, 3, 5, 6 with the line 4′. These follow in the table below:

$P_{14'}$:	0	1	0	0
$P_{24'}$:	A	B	0	0
$P_{34'}$:	1	0	0	0
$P_{54'}$:	$\alpha\gamma D$	$\beta\delta C$	0	0
$P_{64'}$:	$\alpha'\gamma' D$	$\beta'\delta' C$	0	0

The anharmonic ratio of the four collinear points $P_{24'}$, $P_{34'}$, $P_{54'}$, $P_{64'}$, is identical with the anharmonic ratio of the four parameters

$$\frac{B}{A},\qquad 0,\qquad \frac{\beta\delta C}{\alpha\gamma D},\qquad \frac{\beta'\delta' C}{\alpha'\gamma' D}.$$

Calculating the value $\frac{\mu_3-\mu_1}{\mu_3-\mu_2}\div\frac{\mu_4-\mu_1}{\mu_4-\mu_2}$ of the anharmonic ratio of these four parameters numbered in the order in which they are written, we find

$$(P_{24'}, P_{34'}, P_{54'}, P_{64'}) = \frac{\beta'\delta'}{\beta\delta}\left\{\frac{\beta\delta AC - \alpha\gamma BD}{\beta'\delta' AC - \alpha'\gamma' BD}\right\}$$

Recalling the fact that

$$A, B, C, D \equiv (\alpha' - K\alpha),\ (\beta' - K\beta),\ (\gamma' - K\gamma),\ (\delta' - K\delta)$$

respectively, it is easily verified that

$$\frac{\beta'\delta'}{K\beta\delta}\left\{\frac{\beta(\gamma'\delta - \gamma\delta')A - \gamma(\alpha\beta' - \alpha'\beta)D}{\beta'(\gamma'\delta - \gamma\delta')A - \gamma'(\alpha\beta' - \alpha'\beta)D}\right\}$$

$$\equiv \frac{\beta'\delta'}{\beta\delta}\left\{\frac{\beta\delta AC - \alpha\gamma BD}{\beta'\delta' AC - \alpha'\gamma' BD}\right\}$$

Accordingly

$$(P_{12'}, P_{13'}, P_{15'}, P_{16'}) = (P_{24'}, P_{34'}, P_{54'}. P_{64'}),$$

or expressing this in a briefer fashion

$$(2', 3', 5', 6')_1 = (2, 3, 5, 6)_{4'}$$

Since the configuration is a symmetrical one, we have the general conclusion

$$(i_3', i_4', i_5', i_6')_{i_1} = (i_3, i_4, i_5, i_6)_{i'_2},$$

and this theorem may be phrased as follows:—

The anharmonic ratio of the points in which any four out of five co-tractorial lines cut the common tractor of all five is equal to the anharmonic ratio of the points where the fifth line is intersected by the correspondents of the first four.

Let us designate the anharmonic ratio of the four planes formed by the plane i_1' with the lines i_3, i_4, i_5, i_6 by the symbol $\overline{(i_3, i_4, i_5, i_6)}_{i'_1}$. Recalling next the known theorem concerning the two tractors of four lines, viz. that the four points of either tractor and the four planes of the other tractor have the same anharmonic ratio, we obtain

$$(i_3, i_4, i_5, i_6)i'_2 = (i_3, \overline{i_4, i_5, i_6})i'_1$$

and have by our last theorem

$$(i'_3, i'_4, i'_5, i'_6)i_1 = \overline{(i_3, i_4, i_5, i_6)}i'_1$$

which may be phrased as follows:—

*The anharmonic ratio of the four points, on one of five co-tractorial lines, which are collinear with three of the remaining lines is equal to the anharmonic ratio of the four planes determined by these remaining lines and their common tractor.**

For other interesting results on the anharmonic ratios connected with the double-six configuration consult the paper of Kasner just referred to.

§9. *Five Co-tractorial Lines as Primitive.*

Given any five co-tractorial lines, these determine uniquely, as was shown in § 7, the double-six configuration. Then if we consider the plane of *ij'*, it will be met by the lines *i, j* in points which lie on the line *ij*. Since ${}_6P_2 = 15$, the 12 lines of the double-six together with the 15 new lines make up 27 in all, the total number upon the cubic surface.† Then the condition $\Delta_5 = 0$ (§7,), which is the condition that five lines be co-tractorial, is likewise the condition that five given lines may lie in a cubic surface. The result of Sylvester, viz. that $\Delta_5 = 0$ is the condition that five given lines be co-tractorial, is found in a paper on the "Involution of Six Lines",‡ a subject first studied by him in connection with a theorem in the Lehrbuch der Statik, by Möbius (Leipzig).

If we are given five lines, defined by their six co-ordinates

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*Kasner, Am. Journal Math. vol. XXV, No. 2 (1903), p. 114.

†Sylvester, Comptes Rendus, vol. LII (1861), pp. 977–980. Cf. also Salmon, Geom. of Three Dimensions, 4th edition, pp. 500–501 and R. Sturm, Flächen Dritter Ordnung, pp. 57–59.

‡Comptes Rendus, vol. LII (1861), pp. 815–817.

$(a_1, b_1, c_1, f_1, g_1, h_1), \ldots (a_5, b_5, c_5, f_5, g_5, h_5)$, then the condition that these five lines be co-tractorial is also

$$\begin{vmatrix} 0, & 12, & 13, & 14, & 15 \\ 21, & 0, & 23, & 24, & 25 \\ 31, & 32, & 0, & 34, & 35 \\ 41, & 42, & 43, & 0, & 45 \\ 51, & 52, & 53, & 54, & 0 \end{vmatrix} = 0,$$

where we set

$$a_1f_2 + a_2f_1 + b_1g_2 + b_2g_1 + c_1b_2 + c_2b_1 = 12, \text{ \&c.,}^*$$

which is also the condition that these lines may be in a cubic surface.†

The virtual identity of this condition with that of Sylvester ($\Delta_5 = 0$ of §7) is on account of the fact that Cayley's determinant of the fifth order above written is the square root of Sylvester's Δ_5.‡

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*Cayley, Coll. Math. Papers, vol. VII (1867), pp. 66-98.

†Cayley, Coll. Math. Papers, vol. VII (1870), p. 178.

‡Sylvester, Comptes Rendus, vol. LII (186[illegible]), p. 816.

VOL. XXI DECEMBER, 1905 NO. 4

JOURNAL

OF THE

Elisha Mitchell Scientific Society

ISSUED QUARTERLY

CHAPEL HILL, N. C., U. S. A.
TO BE ENTERED AT THE POSTOFFICE AS SECOND CLASS MATTER

Elisha Mitchell Scientific Society.

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Journal of the Elisha Mitchell Scientific Society—Quarterly. Price $2.00 per year; single numbers 50 cents. Most numbers of former volumes can be supplied. Direct all correspondence to the Editors, at University of North Carolina, Chapel Hill, N. C.

JOURNAL
OF THE
ELISHA MITCHELL SCIENTIFIC SOCIETY.
DECEMBER, 1905
VOL. XXI NO. 4

FOOD ADULTERATION.

BY ALVIN S. WHEELER
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The human body is a chemical laboratory in which fires are kept up at night as well as by day. In it the most complicated chemical reactions are carried out, many of which man can neither reproduce nor understand. Some of the complex substances can be made by man at very high temperatures, but the body needs only its own moderate temperature. Here we come face to face with one of the wonders of nature. The food which we eat constitutes the fuel which feeds the fires, and if this is not what it purports to be, then abnormal substances are produced, the machine is thrown out of gear—in short, we are sick. The question of pure food is a vital one. That we do not always get it is absolutely certain. To quote a recent writer: "In these days of butter not traceable to the cow, of wine innocent of the grape, of beer estranged from hops and malt, of coffee-berries made in a mold and not grown on a bush, of honey not made in a beehive but in a factory, and a thousand and one audacious frauds, we consume one hundred million dollars' worth of fraudulently prepared food a year. Fraud has been officially detected in more than three thousand samples of food. From the cheapest and most ordinary article of diet, such as French sardines (caught off the coast of Maine) and canned salmon (with apologies to the swordfish) to such costly delicacies as Russian caviare (collected in Delaware Bay) and imported Lucca oil (from the cotton fields of Georgia), there is imposition." But Americans do not object to this very seriously, perhaps on account of a trait of character portrayed by Dr. Wiley before the Franklin Institute. He spoke as follows: "Barnum made a colossal fortune by acting on the principle that Americans liked to be humbugged. There is something soothingly seductive in being led to the circus by lurid posters showing unattainable attitudes of impossible monsters. This attractiveness is increased by the knowledge that, like the limited express, it implies an extra charge. Were the feats of legerdemain of the mystic Herman actual performances of supernatural powers, they would lose for us half of their charm. To be cheated, fooled, bamboozled, cajoled, deceived, pettifogged, demagogued, hypnotized, manicured and chiropodized are privileges dear to us all. Woe be to that paternalism in government which shall attempt to deprive us of these inalienable rights."

Notwithstanding that food adulteration has caused a good deal of discussion and legislation throughout our land, there is considerable suspicion that it is much ado about nothing. Sooner or later the public will realize the tremendous extent of the fraudulent practices which are in operation. Not only is there danger to the life and health of the consumer, but honest industry is seriously injured. For many years a Pure Food Bill has been before Congress, but so far it has failed to pass. Most of the states, however, have laws which are applicable within their borders. These laws are based upon the English Food and Drug Act, which became a law in 1875. Last November Secretary Wilson, of the Department of Agriculture, approved and proclaimed the Official Food Standards, which had just been formulated by the United States Food

Standard Commission and a committee of the National Association of Pure Food Commissions. It is no simple matter to say what the standard of any particular food shall be, and this recent action only partially covers the ground. The standards consist of definitions and chemical limits, and embrace meat and its products, milk and its products, sugar and its related substances, spices, cocoa and cocoa products. It is hoped that this work will be completed within two years.

The adulteration of food is not a sin of modern times. In London, eighty-five years ago, grocers sold tea made of thorn leaves, dried on copper and colored with logwood and verdigris. Milk was largely made of chalk and water, and sugar was mixed with sand. Only a few years ago a member of my family while in London returned to a grocer some sugar which only partly dissolved in water. The grocer appeared horrified and made the exchange with remarkable rapidity. In the United States the granulated white sugar is as pure as the manufacturer can make it.

The demand for pure food becomes more and more insistent each year, as realization grows of the far-reaching extent of adulteration. A recent bulletin of the North Carolina Board of health reveals how extensively food is now adulterated. The report says that 29 per cent of the vinegar examined was untrue to name; 33 per cent. of the honey was adulterated; 37.5 per cent. of the jellies and jams, and every single sample of apple butter, catsup, and sauces. As I have already said, most of the States have adopted pure food laws, and an immense amount of good has been accomplished through them. Each State has a Food Commission, which keeps a watchful eye upon every variety of food sold within the boundaries of the State. Samples are bought in the open market and carefully analyzed by the chemist of the Commission. Where adulteration is found the violator is prosecuted, and prosecutions are usually successful. In Ohio, during 1901, there were 252 prosecutions. The jury disagreed in only seven cases and there were only nine acquittals. It is interesting also to note the decrease in adulteration. In Massachusetts in 1883 the percentage of samples of adulterated milk was 83. This fell to 28 in 1900. The percentage of adulterations of foods dropped from 31 per cent. to 14.

Milk is most liable to fraud of all the different kinds of food, because the chief adulterant is water, which costs nothing. In Massachusetts three-fifths of the entire appropriation is devoted to the inspection of milk and its allied products, butter and cheese. In the city we are more apt to be confronted with blue milk than in the country. The law in most States requires the presence of twelve parts of solid matter, since the natural product of the cow does not contain less than this, though it may contain much more. The cream rises in a cow's udder the same as if in a milk-pan, and, unless the cow has violently exercised just before milking, the first milk is less rich in butter fat, and this, by some, is sold to the consumer. The last of the milk, called the strippings, is nearly pure cream. The milkman is apt to keep this for his own private butter-making.

Owing to the fact that milk is such a splendid medium for the growth of all kinds of bacteria, which bring about its decomposition, it is an exceedingly common practice for the milk dealer to add some antiseptic, especially formaldehyde, so that it will keep in hot weather and may be transported long distances. On account of the physiological action of formaldehyde it is a menace to the health and its use in milk should be condemned. But this form of adulteration is dangerous from another standpoint: it becomes a substitute for cleanliness and sanitary precautions, which are so essential to the healthfulness of milk. The requirement of cleanliness is appreciated by the modern progressive dairy, which is a model of purity.

In Connecticut the collection of milk samples is made by agents, who are provided with bicycles carrying in the frame a case containing eighteen cans of a half-pint capacity each. The construction is such that one can may be removed without disturbing the others. Between four and seven o'clock in the morning the agent rides from street to street and buys a pint of milk from every milkman whom he meets, without making known the object of his errand. He notes the name of the milkman or of his dairy given on the wagon.

Eggs, of course, cannot be adulterated, but they may be of varying quality, and now substitutes for them are being manufactured. The reasons for this are that eggs are high priced in winter, while in summer they deteriorate too rapidly. On the Boston market one has the privilege of buying eggs of different ages—"strictly fresh eggs," "fresh eggs," and "eggs." An egg may be preserved by evaporating its contents down to the solid state. By maintaining a low temperature, the water, which is the largest constituent, is driven off. This preparation is called La Mont's crystallized eggs. It is an important product, for in one year alone 100,000 pounds, equivalent to 4,800,000 eggs, were shipped to South African miners. In New York they are now manufacturing an egg substitute, called "ovine." It is said to "take the place of fresh eggs in baking." Analysis, however, shows that it resembles the white of an egg in composition, and not the whole egg.

Coffee offers a good field for the fraudulent operations of the manipulator. The coffee berry is imitated not only in the green state, but also in the roasted condition. There are more than six firms in this country regularly engaged in the manufacture of coffee-bean making machinery. Bogus berries are ground out by the ton, and they are better looking than those that grow on the bush. A paste is made of chicory, starch, pea meal, caramel, and molasses, molded into the proper shape and dried. The pure-food laws have had a very beneficial influence upon coffee adulteration. In one State the percentage of adulterated samples fell in two years from 63 to 25. The adulterants of ground coffee are peas, chicory, wheat rye, and bean hulls. So-called coffee compoundr are mixtures of coffee with other substances, such as cereals. Sometimes the packages are properly labeled, and again they are not.

Another indispensable beverage is tea. The extent of its use is indicated by the statement that in a recent year ninety-four million pounds were imported into the United States. Tea is adulterated with soapstone, gypsum, iron dust, and sand; also with lie tea, the trade name of a mixture made up of tea dust and other matters made into lumps with starch paste and colored. Tea is also mixed with exhausted tea leaves and leaves of the beech, willow, elm, rose, and wistaria. Finally, all of the green tea and a good deal of the black tea is faced or coated to impart a gloss and an attractive color. Prussian blue, indigo, and soapstone are used for green teas, and plumbago or black lead for black teas.

Cocoa and chocolate are making remarkable headway as beverages. Coffee and tea have been objected to on hygienic grounds, and substitutes are being extensively used. Cocoa is more nourishing than any other beverage, and perhaps as sustaining. Cocoa beans are reddish brown in color and resemble lima beans in shape and size. They are first roasted, a chemical change occuring which developes a very desirable flavor. They are next crushed by machinery to separate them from the shells. The broken cotyledons, free from shells, are known as cocoa nibs. These are ground, and the heat of grinding melts the fat which makes up one-half of their weight, and the ground product runs out as a thin paste. This is allowed to cool in molds, and constitutes our unsweetened chocolate. Cocoa is prepared by removing a part of the fat by pressure and reducing the residue to a powder. Cocoa is made inferior by grinding the beans with the shells on. It is adulterated by adding extra shells as well as wheat flour, cornstarch, and sugar, and this is a common practice.

Beneath the beautiful exterior of the soda fountain sit enthroned a host of frauds. We complacently enjoy the beautifully colored drinks with the idea that they are made of natural fruit juices, such as strawberry, cherry, raspberry, and many more. Some dispensers use the real fruit, but very commonly the syrup is made by dissolving granulated sugar in water colored and flavored with substances made in a factory and, finally, in some cases, soap bark is added in order to produce a fine foam. The variety of drinks is very extensive, one wholesale house alone offering an assortment of three-hundred and thirty-three syrups. The artificial extracts made to imitate strawberry, raspberry, and certain other fruit juices are especially obnoxious and give rise to indigestion. Coal-tar dyes are used for coloring purposes, especially for the brilliantly colored drinks seen at State fairs and summer resorts. In Minnesota recently it was discovered that an alleged sweet-apple cider came "fresh from a cider-press" to which the juice was delivered by an underground pipe.

The most palatable and costly sugar is maple sugar. It is an important product, about five million pounds annually coming mostly from Vermont, New Hampshire and Ohio. The great metropolis of the West is also noted for its prodution. A small quantity of the pure article serves to produce large amounts of "maple syrup." To such an extreme is this carried that there is not left even a smell of the real maple. Adultertion is extraordinarily extensive, and it has invaded the maple woods. The reasons are succinctly stated by the Illinois Food Commissioner as follows: "First—It is so easy any one can do it. Second—It is profitable. Third—Adulteration being common, the manufacturer is compelled to follow suit in order to compete in price. Fifth—The production of maple syrup is less than the demand. Sixth—The undoubted demand for a syrup with a slight maple flavor at a less price than the pure product commands. Seventh—The questionable fact that certain varieties of maple (Canada, North Minnesota)yield a syrup of stronger flavor than consumers demand." The adulterants or substitutes for the maple sugar are cane sugar, beet sugar, glucose, and dextrin. To produce the maple flavor extracts of walnuts, butternuts, and corn-cobs are used.

A pure fruit jelly is made entirely from the fruit juice with. the addition of cane sugar. The adulterants are numerous

The jellying quality may be imparted by starch paste, gelatin, or agar-agar, a gelatinous material obtained from sea-weed. These, of course, have no taste, but by adding a coloring matter and some flavoring extract we have at once currant jelly, grape jelly, or any kind whatsoever. Glucose is much used for sweetening purposes, although it is less sweet than cane sugar, the ratio of sweetness being about three to five. In one year the Connecticut station found twenty pure jellies and forty-three adulterated, the first being home products, while the adulterated were factory products. Jams also are not always what they seem to be. A sample of strawberry jam recently analyzed in Nebraska was found to consist mostly of pumpkin, tinted with coal-tar dyes, preserved in benzoin, with grass seed thrown in to make the jam look like the real thing.

Honey in the comb probably cannot be adulterated except by the bee itself, which seems to have a monopoly on capping the cells. That the inventive American has made many attempts to produce a machine which would do this work there can be no doubt. Strained honey is readily adulterated, glucose being the usual adulterant. Sometimes only sufficient real honey is added to impart a slight honey flavor. A glass jar of glucose with pieces of honeycomb floating in the liquid makes a beautiful deception and a very profitable one.

Spices afford a very attractive field for the sophisticator. Allspice has been found in some cases to contain as much as 85 per cent. wheat and nut shells. Cayenne is adulterated with corn, wheat, ginger, and a red aniline dye. Cloves may contain wheat, sawdust, charcoal, and factory sweepings. Ginger is adulterated with wheat, rice, and pepper. Mustard is liable to contain mustard hulls, corn, wheat, and rice sometimes to the extent of 90 per cent. Pepper is adulterated with wheat, ginger, pepper shells, olive stones, and buckwheat,

The labeling of food products is a matter of considerable importance, because it is from the label that we usually get our ideas of the character of the goods. Labels are wholly deceptive. Such words as "high quality," "high grade," "excellent quality," "pure," and "unadulterated," are often found attached to articles of the most worthless character. Various devices are employed to lead the unwary astray. Here is a label:

LEMON EXTRACT

Alcohol, 415.	Aqua, 450.	Oil Lemon, 15.

The resort to the Latin word is a fraud of low order. The extract actually contained more water, less alcohol, and no oil of lemon whatever. On a box of powdered borax put out by a New York house was found the following caution: "Avoid the many spurious imitations of our borax with which the market is flooded, and which can only do harm to those who use them. See that our trade mark is on every package." The chemical examination of this borax showed that every package was seriously adulterated with bicarbonate of soda.

Again on a package of coffee, the statement "Made of pure coffee and cereals" is placed perpendicularly, and the instruction to "Open this end" placed at the opposite end.

The food laboratory in the Bureau of Chemistry, United States Department of Agriculture, is now engaged in investigations of the highest importance. Under Dr. Wiley a squad of men take their meals at the Bureau's laboratory, the food being doctored with borax, salicylic acid, and other substances which are said to be deleterious to health. The experiments are extremely interesting, and the results promise to be important.

In conclusion it may be said that all adulterations are not harmful; in fact, many are actually wholesome. A watchful eye is required to detect the serious abuses, which are all too common, and it is necessary to distinguish between the harmless and harmful frauds. The press is prone to exaggeration —a practice vividly portrayed by Bob Burdette in the following poem, entitled "A Victim of Delusion:"

Placid I am, content, serene;
  I take my slab of gypsum bread,

And chunks of oleomargarine
  Upon its tasteless sides I spread,

The egg I eat was never laid
  By any cackling feathered hen;
But from the Lord knows what 'tis made
  In Newark by unfeathered men.

I wash my simple breakfast down
  With fragrant chicory so cheap;
Or with the best black tea in town—
  Dried willow-leaves—I calmly sleep.

But if from man's vile arts I flee,
  And drink pure water from the pump,
I gulp down infusoriæ
And hideous rotatoriæ
And wriggling polygastricæ
And slimy diatomaceæ
And hard-shelled orphryocercinæ
And double-barrelled kolpodæ
Non-loricated ambrœilæ
And various animalculæ
Of middle, high and low degree;
For nature just beats all creation
In multiplied adulteration.

[By permission of the Outlook Company.]

NOTES ON THE SCUTELLATION OF THE RED KING SNAKE, OPHIBOLUS DOLIATUS COCCINEUS, SCHLEGEL.

C. S. BRIMLEY.

"Body color scarlet, completely encircled by pairs of black rings, with interspaced white in the young, yellow in the adults: no lateral spots, top of head red, with the first black ring crossing the parietals. The pattern is formed by the obliteration of the lateral portion of the black borders of dorsal spots, and the extension of their transverse portion entirely around the body. The lateral spots have disappeared" (From "A Review of the Genera and species of North American Snakes, North of Mexico," by A. E. Brown, Proc. Acad. Nat. Sci, Phila, Jan. 1901). According to Brown the normal scutellation would seem to be 21 rows of scales, loreal present, one temporal in the first row, the rows of scales occasionally varying to 19, and the loreal sometimes absent, this extreme form being the Osceola elapsoidea *B. and G.*

Cope treats the two forms as a distinct species, and gives the scutellation as loreal present, two temporals in first row, and rows of scales 21 for *coccineus*, and loreal absent, one temporal in first row, row of scales 17 or 19 for *elapsoidea*. (Crocodilians, Lizards and Snakes of North America, by E.D. Cope, Report of U S. Nat. Museum, 1898.)

My experience is that the normal formula is, scales in 19 rows, occasionally 17 or 21, one temporal in first row, occasionally two, and loreal usually present, but sometimes absent on one or both sides.

The specimens that I have examined with reference to some or all of these points are

A. Specimens from Bay St. Louis, Miss.

No.	Length.	Loreals	Temporals	Scales	Examined
1	21 inches	1–1	1–1	19	Mch. 11.'01
2	21 "	1–1	1–1	19	" " "
3	8 "	0–0	2–2	19	" " "
4	10 "	1–1	1–1	19	" " "
5	15 "	1–1	1–1	19	" 19 "
6	12 "	1–1	1–1	19	" 25 "
8	240 mm	1–1	1–1		alcoholic 3607
9		1–1	2–1	19	" 3654
10		1–1	2–?		" 3055
11		1–1	1–1	19	" 3058
12		1–1	1–1	19	" 3045
14		1–1	1–1	19	" 3057
15		1–1	1–1	19	" 3056
16		0–0	1–1	19	" 3044

B. Specimens from Raleigh, N. C.

No.	Length.	Loreals	Temporals	Scales	Examined
7		0–0	1–1	19	Apl. 26,'01
13		1–[illegible]	2–2	21	alcoholic 3059
19		0–0			May 10'05
20	180 mm	1–1		19	alcoholic 5524
21	150 "	1–?	1–1	19	" 5523
22	450 "	0–?	2–1	21	" 3682
23	240 "	0–0	0–0	19	" 3683

C. Specimens from Florida.

No.	Length.	Loreals	Temporals	Scales	Examined
18	from Orlando	0–0	1–1	17	" 2330
17	from Tarpon Sp	1–1	1–1	17	" 2488

NOTES ON THE ABOVE SPECIMENS,

No. 2 has the nuchal yellow collar divided in the center by a longitudinal bar of black.

10 has both red and and white rings more or less interupted on the belly by black.

13 has the adjacent black rings uniting on the belly, enclosing the red dorsal spots.

20 has the white rings mainly interrupted more or less on the belly by black blotches, while the red rings are uninterrupted.

21 is typical coccineus, in color, but has the loreal reduced on one side to a small triangular plate at the junction of the prefontal, nasal, and 1st and 2nd upper labials.

22 is neariy typical cocineus, but has black spots on the belly opposite the white rings. Several of the head plates peculiar. The loreal is absent on one side and represented on the other by a triangular plate cut off front of prefontal and extending to the labials.

23 has red spots closed by a partially divided black tract on middle line of belly. Black spots on belly opposite the white rings are present on latter half of belly only. Sixth upper lacial on each side reaches to the parietals and suppresses the temporals.

Summary. The Mississippi specimens all have 19 rows of scales, except two not examined for that point, twelve of them have the loreal present on both sides of the head, and two of them have it absent on both sides: eleven have one temporal in the front row on both sides, one has two temporals on both sides, one has one temporal on one side and two on the other, and the last has two temporals on one side and the scutellation could not be made out on the other.

Of the Raleigh specimens four have 19 rows of scales, and two have 21, while a seventh was not examined for that point. Two have a loreal on both sides, three have the loreal absent on both sides, while of the remaining two, one has loreal present on one side and represented by an abnormal plate on the other, and the other has loreal absent on one side and represented by an abnormal plate on the other. As to the temporals two specimens have one in first row on each side and two more have two on each side, a fifth has two on one side and one on the other, while the sixth has the temporals completely absent. The seventh was not examined on that point.

The obvious conclusions are that the normal scutellation is 19 rows of scales, loreal present, and one temporal present in the first row. The most curious feature is the large percenage of Releigh specimens with the loreal absent or abnormal on one or both sides, a feature we would naturally expect in the more southern specimens rather than in the northernmost of those examined.

NOTES ON THE FOOD AND FEEDING HABITS OF SOME AMERICAN REPTILES.

C. S. BRIMLEY.

The following notes are from personal observations made during the past ten or twelve years on various reptiles, both wild and in captivity.

Taking the snakes first, their method of swallowing their prey deserves attention, and to understand this it must be remembered that both the upper and lower jaws and the teeth-bearing bones of the palate are united by ligaments only, thus rendering the mouth capable of very great dilation. Furthermore, any ordinary harmless snake has four rows of sharp backwards pointing teeth in the upper jaw and two rows in the lower.

Now, when a colubrine snake, a Spreading Adder (*Heterodon platyrhinus*) for instance, seizes its prey, in this species always a toad, it at once commences, so soon as it has a good hold, to work one side of the jaws forward over the animal with a chewing motion; then when it has worked that side as far as possible it takes a firm hold with that side and works the other side forward over the animal alternately until it is well within the mouth, when it is pushed down into the stomach by the muscular contraction of the body; the snake in fact literally glides over its prey, after it is once safely inside, often pushing it down by crawling forward with its side pressed against some hard object.

In the case of *Coluber obsoletus* or any other of the chicken snakes swallowing a hen's egg, an apparently impossible feat when one sees the snake and egg side by side, the modus operandi is exactly the same, except that the snake has to get the egg in a position where he can push his mouth over it without it rolling away, in the corner of a box for instance. The egg so far as I can make out passes into the snake's stomach whole and unbroken and the shell being dissolved by the digestive fluids, its contents are released and digested.

Those harmless snakes which have but little constricting power, such as the various species of Water Snake, the Garter Snakes, Green Snake, and Spreading Adder,simply catch their prey and swallow it alive and whole without further dallying. The Snakes of the genera Ophibolus (Lampropeltis,) Pityophis, Coluber (Callopeltis,) Bascanion and Spilotes, commonly known as King Snakes, Bull Snakes, Chicken Snakes, Black Snakes, Coachwhips, and Gopher Snakes have however very considerable constricting power as may be easily proved by allowing a good sized specimen of any of these genera to coil itself round ones wrist, but to what extent they habitually kill their prey by this means I do not know. The common black King Snake with white rings whose food consists of rats, mice and other snakes kills the latter in its coils before swallowing them, but how it treats the former I do not know. On one occasion I had placed a King Snake, possibly some 18 inches or 2 feet long in a box with a number of other snakes all considerably larger than itself, almost immediately it glided up to a large Black Snake and seizing it by the head wrapped itself in a tight spiral coil round the forepart of the latter's body. The Black snake however thrashed about so violently that the King had to let go,and when the latter again attempted to seize him the Black Snake struck him on the head which cooled off his ardor and there was no further trouble between them. On another occasion I placed a large King Snake in a box with a smaller Black Snake, and the former seized the latter by the head and crushed the life out of him in his coils, but releasing the Black Snake's body little by little as he swallowed it. I once saw a Chicken Snake,I think it was the striped southern species *Coluber quadrivittatus*, kill a young fledgling bird which I had placed in the same box with it crushing it to death in a U-shaped fold of the snake's body. These snakes all swallow their food in precisely the same way as the Spreading Adder, which is the usual method with snakes. The constricting power of the genera Ophibolus and Coluber is much greater than those of the genus Bascanion (Black Snakes and Coachwhips).

Of the amount of food consumed by snakes I have four records. The first is that of a poisonous snake, a Copperhead (*Ancistroden contortrix*) an average sized adult, which grew fat and improved greatly on the following diet: 1897, Aug 7, small bird; Aug 12, ditto; Aug 19, ditto; Aug 25, ditto; Aug 30, 1 mouse, Sep 10, 14, and 19, one small Cotton Rat on each date. In 44 days it ate nine times, never eating more than one small bird or animal on any one day, though more than that number were sometimes offered it. All the specimens were dead. The snake improved in girth and color and some chafed places on its neck entirely disappeared.

The second record is that of a 33 inch Rat Snake or Spotted Racer (*Coluber guttatus*) which did well on the following rations:—1897, July 29, one bat; Aug. 7, one small bird; Aug. 10, 12, 17, and 19, one bat on each date; Aug. 23, one small bird; Aug. 30, one bat; Sep. 14, one mouse; Sep. 20, one shrew In 54 days it ate ten times, in 31 days it ate seven times.

The third and fourth records are of the Spreading Adders, one of which ate ten toads from Aug 6 to Sep 11, 1897 (ten toads in 86 days,) and another twelve toads from Ang 6 to Sep 9, 1897 (twelve toads in 34 days).

The food of the various species of snake that have come under my notice is as follows, so far as my observations go,—

Spreading Adder(*Heterodon Platyrhinus*): toads (Bufo) only.

Water Snake (*Natrix sipedon*): fish, toads.

Garter Snakes (*Eutaenia sirtalis*): toads.

Ribbon Snake (*Eutaenia saurita*): small frogs, small salamanders.

Chicken Snakes (*Coluber obsoletus, C. o., confinis, C. o.,* *lindheimeri, C. quadrivittatus*): rats, mice, small birds up to size of quail, young birds, bird's eggs, hen's eggs.

The Bull Snakes (*Pityophis sayi and P. melanoleucus*) same food as the Colubers.

Spotted Racer (*Coluber guttatus*) has not been observed to eat hen's eggs, but otherwise its food seems to be much the same as the other Colubers, although I think it shows a much greater preference for rats and mice: and the same remarks apply so far as my experience goes, also to the Black Snake (*Bascanian constrictor*) and the Coachwhip (*Bascanian flagellum*).

King Snake (*Ophibolus getulus*): rats, mice and other snakes.

Brown King Snake (*Ophibolus rhomboamaculatus*): rats, mice and lizards.

Red King Snake (*Ophibolus coccineus*): lizards, (Eumeces and Liolepisma).

Green Snake (*Cyclophis aestivus*): large insects such as larval katydids and the caterpillars of the Silver-spotted Skipper.

Brown Snake (*Haldea striatula*): earthworms.

With regard to the food of lizards, I cannot say much. The smaller species however eat insects of various kinds, the common rusty Fence Lizard (*Sceloporus undulatus*), and the Green Lizard (*Anolis principalis*), commonly though erroneously known as "Chameleon," having been observed in confinement to eat house flies, young grasshoppers, and small butterflies, while the Bluetailed Lizard (*Eumeces fasciatus*) commonly known as "Scorpion" in the South, has been observed to eat house flies, butterflies, small carabid beetles, earthworms, cockroaches and large, smooth caterpillars, but bright colored butterflies were not liked. The so-called Glass or Joint Snake (*Ophisaurus ventralis*) has been observed to eat Katydids, large Bird Grasshopper (*Schistocera americanum*) and large butterflies such as the swallowtails. The other legless lizard of the eastern United States, the curious Florida Blindworm (*Rhineura floridana*) which superficially looks more like an earthworm than a lizard, apparently eats earthworms, as in 1900 I kept some for several months and used to put earthworms in the box of earth in which they were kept, and the said worms uniformly disappeared without leaving any trace behind.

Only one other lizard has come under my notice in captivity, viz.: the big Gila Monster (*Heloderna suspectum*) of Arizona and this in captivity seems to confine itself mainly, if not entirely to hens' eggs, which when broken on a plate are lapped up by its broad fleshy tongue. My notes on this species are as follows:—1898, July 9, one large one received, drank water; July 11, ate 3 eggs; July 12, ate two; ate nothing from July 13, when he ate one egg, till July 22, when he ate another, not in the meanwhile eating eggs when offered to him. From July 23 to Oct 25 he ate 25 eggs, eating one every three or four days and fattened on the diet. 1899, three Heloderma received May 2, sent off May 9, ate 17 eggs in 8 days. 1899, three more received May 23, sent off May 30, ate 21 eggs in 8 days.

The Testudinata, of which the different species are indiscriminately known as turtles, tortoises, and terrapines the last name being in the South applied to nearly all species except the Snapping Turtle, comprise both omnivorous, carnivorous, and herbivorous species.

The Gopher of Florida (*Xerobates polohemus*) is a good example of the first group, feeding only on succulent plants of various kinds, those I had showing most partiality to nutgrass, although they would also eat corn leaves, zinnia leaves and stems, sowthistles (Sonchus) and also apple peel and pieces of apple. Several of the aquatic species are also mainly herbivorous, especially the Painted Turtle, *Chrysemys picta*, which in 1900 ate greedily of cabbage leaves, although they also have been observed to eat raw flesh, chicken offal, corn bread, pieces of watermelon and canteloupe. They usually drag their food into the water and eat it with the head under water. On July 16, 1900, however, I saw one eating a piece of canteloupe on land without taking it into the water. *Pseudemys concinna*, the large smooth terrapin of our rivers, is also apparently herbivorous, at least I have never detected one in the act of eating flesh. Our other species of Pseudemys, however, the Rough Terrapin (*Pseudemys scripta*) is an omnivorous feeder eating raw flesh, ripe fruit, and the leaves of succulent plants. Like the two preceding it eats its food, mainly at least, under water. The terrapins of the genus Chelopus seem to be more omnivorous than Chrysemys or rather to show a less decided preference for vegetable food. The Speckled Terrapin (*Chelopus guttutus*) has been observed to eat apple, pieces of watermelon, sonchus leaves, dead snakes, fish scraps, etc, usually taking its food into the water to eat it; the other two species of the genus, however, (*Chelopus insculptus* and *C. muhlenbergii*) seem tc eat their food mainly on land, but are however more terrestrial than *C. guttatus* which is in its turn less aquatic than *Chrysemys picta.*

The Box Tortoises or Highland Terrapins of the genus Terrapene (Cistudo) which are terrestrial and not aquatic have been seen to eat raw flesh, dead birds, ripe and unripe fruit such as apple, tomato, watermelon, canteloupe, plum and persimmons and also occasionally the leaves of succulent plants. June bugs are also eaten during the period of their abundance. Their usual method of eating is to stretch the head forward towards their food, seize a piece in the jaws, and then jerk or pull the head backward so as to tear or cut the piece away, the forefeet being usually braced against the food or placed on it, while the portion to be swallowed is torn away. The morsel of food is then crushed sufficiently by the masticating surfaces of the jaws (turtles have no teeth) and swallowed. There is no difference so far as I have been able to observe in the food of the different species of Terrapene, and I have had opportunities for observing *T. carolina*, *T. major*, *T. triunguis*, *T. ornato*, and *T. bauri*.

The Mud Turtle (*Kinosternon pennsylvanicum*) is apparently like the rest of its family carnivorous, never having been observed by me to eat vegetable food. This species and the others of the same genus are the only turtles that cannot support themselves in deep water without something to rest on, and if one is placed in a tub of water where it cannot support itself on something so as to get its head out of the water, will soon become exhausted from its struggles to reach the surface and drown. All our other genera of turtles both aquatic and terrestrial, including the nearly related Aromochelys which by the way is thoroughly aquatic, float without any difficulty whatever.

Of our other species of Testudinata I have no observations to record except that a Snapping Turtle in the posession of the State Museum used to eat live toads, dragging them under water to swallow them.

THE SOUTHERN APPALACHIAN FOREST RESERVE.

BY JOSEPH HYDE PRATT.

The forest wealth of North Carolina and Tennessee makes the establishment of a Southern Appalachian Forest Reserve of very great interest to these States; but as these forests affect industries throughout all of the Southern States, and thus affect the industries of the entire country, the establishment of this Forest Reserve is a matter also of national interest and concern. One hundred years ago there was little or no attention given in this country to the method or means by which its forests were cut away; that is, whether they were cut for lumber or ruthlessly destroyed in the clearing of land for agricultural purposes. There was no thought paid to the prevention of forest fires because they were harmful to the forests themselves; and no thought whatever was given to the influence that forests exert on the flow of streams and rivers. At that time there seemed to be a superabundance of lumber for all purposes, the wasteful destruction of which could not then be felt. Forest fires were not considered as doing any particular harm as long as they did not come too near the habitations of men. The streams and rivers always contained plenty of water and for a quarter of a century not enough land was cleared of their forests to demonstrate the effect their removal had upon the water supply.

At the beginning of the 20th century, however, there has been a decided change in the views and ideas regarding the value to a country of its forest resources. Thus, our leading statesmen and our citizens realize and appreciate not only the commercial value of the perpetuation of our forests, but also the vast influence that these forests exert in the preservation of the water supply of the country. Perhaps their most noticeable influence is in mountainous and hilly countries, which, when covered with abundant forests, prevent the soil from being washed away and by the decay of their leaves form a loam which prevents the waters from running off the surface too rapidly. It is these forest-covered mountains that are extremely valuable because of the effect they have upon water supply and water powers.

By the removal of the forests there is no longer a protection for the soil on the slopes of the mountains and hills except that produced artificially in the form of ditches, etc. There is no longer a layer or bed of leaves to act as an absorbent for the water and a preventive to its evaporation and it runs off for the most part as fast as it falls, causing high freshets and floods and periods of extreme low water; causing the streams and rivers to be higher at times of floods but very much lower the greater part of the time than they were before the removal of these forests. This is well illustrated at the present time in many parts of eastern United States where many of the rivers are not navigable to the extent that they formerly were and many of them are a constant expense to the government in keeping them open to navigation due to low water. While a great deal of harm has already been done in this way, a still greater harm will be done if the remaining forests are not protected. It is not only the navigation of the streams and rivers that is hurt by the removal of the forests but also the water supply for our cities and towns. Many of our largest cities are already beginning to find some difficulty in storing a sufficient supply of water for their use.

This preservation of the forests means also the maintenance of the water powers, which, if reduced or destroyed, will seriously injure many of our manufacturing interests.

These defects in the water supply are not due to the lack of rain but to the removal of the natural agencies that nature has provided for the storing of this water which has resulted from the removal of the forests. Again, these defects are not due to any considerable extent to the clearing of land for farming purposes for the farmer must of necessity protect the soil from being washed away and the only loss to the water supply that he would cause would be the greater evaporation to which it would be exposed. They are, however, due to the wasteful and destructive removal of the forests by the lumber companies who leave large tracts of land stript in some cases of every vestige of a tree.

The present method of cutting timber and the subsequent forest fires is causing a scarcity of lumber, especially of the hard woods, and there are now but few sections in this country where virgin forests of this character are to be found. This total destruction of a forest in lumbering is not necessary but it is a wasteful destruction of property, and a forest-covered area which should be a constant source of revenue, becomes in the end waste land and in many cases an impoverished, barren tract.

This scarcity of hard woods can be remedied by the application of practical forestry which would be adopted in any forest reserve established in the Southern Appalachian Mountains and is now being practiced in the forest reserves of the western part of this country. There is little or no doubt but that the forests of the Southern Appalachian mountains can, by systematic and conservative measures, be made to yield profitable returns to the State and country. The forests of North Carolina and Tennessee are, and have for many years, been one of the chief resources of revenue to the people of these States and thus their preservation and perpetuation means a constant source of revenue to these States.

Thus the two main and vital reasons for forest reserves are first, the protection of the water supply of our streams and rivers; and second, the protection of our supplies of lumber, especially the hard woods.

The region that is to comprise the proposed Appalachian Forest Reserve lies for the most part in Western North Carolina and eastern Tennessee, with smaller areas in southwestern Virginia, northeastern Georgia and northwestern South Carolina. The slopes of the mountains in this region are the sources of many large rivers, as the Tennessee, the Savannah, the Broad and the Catawba. The water-power and navigation of these rivers are seriously affected by the removal of the forests in the mountainous districts as is also the water supply for the towns and cities in the vicinity of the mountains and of these rivers. This southern section of the United States has not been subjected to glacial action as the northern States have and there are, therefore, no glacial drifts in this region to act as storage reservoirs for water. Thus, in the removal of the forests we are practically removing all the natural resources for storing water.

In speaking of forest reserves and particularly of the proposed Southern Appalachian Reserve, President Roosevelt in his address at Raleigh, N. C., October 20, 1905, pointed out how vital the preservation of the forests is to the welfare of every country and that the upper altitudes of the forested mountains are most valuable to the nation as a whole, not only on account of their commercial value as supplies of lumber, but especially because of their effects upon the water supply. He further said: "Neither state or nation can afford to turn these mountains over to the unrestrained greed of those who would exploit them at the expense of the future. We cannot afford to wait longer before assuming control, in the interest of the public, of these forests; for if we do wait, the vested interests of private parties in them may become so strongly intrenched that it may be a most expensive task to oust them. If the Eastern States are wise, then from the Bay of Fundy to the Gulf we will see, within the next few years, a policy set on foot similar to that so fortunately carried out in the high Sierras of the west by the national government. All the higher Appalachians should be reserved, either by the states or by the nation. I much prefer that they should be put under national control, but it is a mere truism to say that they will not be reserved either by the states or by the nation unless you people of the South show a strong interest therein."

North Carolina, which would give the largest area to the Appalachian Forest Reserve, is unequalled in its variety of hardwoods and conifers by that of any other State or Territory. Throughout the whole area of the State, the great variety of soils and climate has brought together trees from all parts of eastern America so that 24 kinds of oaks are to be found in the State, which is three more than occur in any State to the north of this one, and two more than are to be found in any State to the south; of the nine kinds of hickories known to occur in the United States, eight have been found in North Carolina; here are all six maples of the eastern United States; all the lindens; all six of the American magnolias; three of the birches; eight pines out of eleven; both species of hemlock and balsam-fir; three elms out of five; six arborescent species of plum and cherry; and three of pyrus (apple).

The bleak and exposed mountain summits, bear forests of trees which there find their southern limit, but extend northward through northern New York and New England to Canada. Such trees are the black spruce (the balsam), striped and spiked maples, mountain sumac, which is really an apple, balsam fir and aspen, all unless sheltered by other trees or by the slopes of the mountain above them, rugged and dwarfed from the cold and constant wind to which they are exposed.

The commercial forest trees are on the slopes of the mountains and in the ravines and valleys. Some of these trees have wide distribution to the north of North Carolina or to the south of it, or in both directions, and some of them are restricted in their distribution to North Carolina or to the region around the southern Appalachian mountains.

The mossy cup, yellow and shingle oaks, white linden and big shag-bark hickory, prominent trees of the central States, extend as far to the southeast as central North Carolina; while trees of the north, like hemlock, sugar or hard maple, northern red oak, cherry, birch and white pine, and of the northeast, like the pignut hickory, chestnut, northern pitch pine and balsam enter more or less largely into the composition of the forests of the western parts of the State.

Many trees of wide distribution, and among them some of the most valuable, extend from this State in all directions, the white, post, black, scarlet and Spanish oaks, the red and white maples, the white hickory and brown heart and shagbark hickories, short-leaf pine, yellow poplar, red cedar, black cherry, and black walnut. The cypress, water and willow oaks, downy poplar, swamp-white oak (Q. Michauxii, Nutt.) southern elm, and planer trees are trees having a great range to the south and southwest. A few trees are found only in this State, or extend but a short distance beyond its boundaries, the yellow-wood, the large-leafed umbrella tree, the Carolina hemlock, the clammy locust, the last being entirely confined to this State.

Altogether there are 153 kinds of woody plants, which form a simple upright stem and attaining arborescent proportions growing naturally within the State; and of these over seventy are trees of the first size, and fifty-seven are trees of great economic value. Fourteen of these are known to attain in this State a height of over 100 feet, three of them a height of over 140 feet, sixteen of them reach in this State diameters of five feet or over; and five reach diameters of seven feet or over.

The areas of the other States included in the proposed Forest Reserve also contain a large variety of trees and thus this region contains the greatest variety of hard woods to be found anywhere on the American Continent for it is here that there is an intermingling of the sylva of the north and south. Here trees that are common to New England are found in close proximity to those that are common to the more Southern States. Here is the largest area of virgin forests to be found in the Southern Appalachian region. Here are trees from five to ten fieet in diameter which often tower to a height of 140 feet. The destruction of such a forest would be an almost irreparable loss, for once destroyed it would take generations for its restoration, with a great probability of failure; and then again the chances are that it would not be attempted.

These areas of timber are being rapidly acquired by those whose one object is to make the most profit possible out of them at the present time with no thought for the future. Many of the older countries, as Germany and England, have suffered to such an extent by the destruction of their forests that they, especially Germany, have begun already to take measures to preserve their forests and to make them such that they will be a constant source of lumber, and Germany has shown that by her system these forest reserves become self-supporting. England has become so depleted of her timber that she is obliged to import the greater part of her lumber.

The only remedy for the protection and preservation of our forests is for the National Government to obtain possession of them and to care for them by the application of scientific methods.

Such a forest reserve under the management of trained forest experts will demonstrate how these forests can be perpetuated and at the same time be made to pay. Such an example will have an influence on the several States and individuals by encouraging them to practice forestry and to use those lands for growing timber that are more suited for this purpose than for farming industries. It will be an object lesson and a laboratory for those studying or interested in forestry.

The acquirement of this land by the national government for a forest reserve will not be setting a precedent for, "nearly 50,000,000 of acres of forest covered lands have been set aside (in the Western States) as National Forest Reserves and parks for the purposes of perpetuating a timber supply in the Western States and territories and for preserving forever the sources of their more important streams." Thus what is now proposed is not new either in principle or practice. There are a number of reasons that can be given why this should be a National Forest Reserve. First, the problems and dangers that it is intended to meet are national; second, this tract of land lies in several States and the streams that rise in them flow through many States and it would be difficult, even if possible, for these States to control and operate such a reserve successfully; third, these States are not so situated financially that they could even make the attempt to carry out this plan. Thus if the forest reserve such as is contemplated is established it must be done by the National Government. The several States have conferred upon Congress the necessary authority to acquire land within their respective borders. These lands can at the present time be purchased at a very reasonable price; but they are increasing in value from year to year. While there are these fifty millions of acres in National Forest Reserves and Parks in the West there is not a single National Forest Reserve in the East. (There are a few State Reserves.)

The withdrawal of this large amount of land and putting it into the hands of the Government will not prevent the development of its other resources (mineral and agricultural) for these can be developed as fast as capital desires but under the judicial guidance of the Government and it is possible for large industries to become established in them.

Besides being a forest reservation, this tract of land will also be a large National Park, though this is a secondary consideration. It will be a National Park that will contain scenery of rare natural beauty and will contain the highest mountains east of the Rocky Mountains and which are covered with trees and shrubs to their summits. The healthfulness of this region is already known throughout the country and this and the climatic conditions are very favorable to a Park.