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TRANSACTIONS

OF THE

WISCONSIN ACADEMY

OF

SCIENCES, ARTS AND LETTERS.

VOL. VIII.—1888–1891.

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(Term expires December, 1893.)

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THE SECTIONAL FEATURE IN AMERICAN POLITICS.

By HUMPHREY J. DESMOND.

It is not always easy to determine the main threads of political history; but in the century of American Presidents, ending with the month of April, 1889, one intermittent and ever recurring question has been that of sectionalism. And the question waits among the perplexities of the new century.

There are grounds for regarding it as thus far *the controlling fact* in American politics. It was an overshadowing issue long before the slavery agitation was launched, and it continues a problem of to-day, long after slavery has ceased, and the irrepressible conflict has been fought out. All the larger events of the constitutional epoch carry a significance to the fact of sectionalism, gain an interest and importance from their relation to that fact, and may be grouped along its length as off-shoots from the main stem.

The theory which regards the constitution as a "compact between the states" may have been true in a formal way, and on that account plausible among the doctrinaires; the essential condition, however, was not a union of states, but a treaty of alliance between two great sections having opposite civilizations and diverse interests. And it is this condition, and not a theory, that confronts us in our survey of the first century in American politics.

The theory figured on both sides of Mason's and Dixon's line — the Hartford Convention being no less extreme a manifestation of states' rights than the episode of nullification. But the condition never fluctuated nor lost its consistency or purpose. It continued from the first to

> "Divert and crack, rend and deracinate
> The unity and married calm of states."

New issues were sought from time to time, but they were merely temporary aberrations. There was the trivial controversy, which for many days, went on in the convention of 1787, between the larger and the smaller states. Even then, the greater question was waiting. The absurd fear of the smaller states that a closer union would result in their absorption by the larger commonwealths being allayed, Madison admonished his colleagues that the states were divided into different interests, "not by their difference in size, but by other circumstances; the most material of which resulted partly from climate, but principally from the effect of their having or not having slaves. It did not lay between the large and small states. It lay between north and south."

Having satisfied the smaller states with equality in the senate, the convention proceeded to its vital act of compromise, by establishing equilibrium between the sections — equalizing their strength in congress and in the electoral college.

No explanation has ever been offered as to how the particular fraction, "$\frac{3}{5}$", was selected in determining what weight the number of slaves should have in the apportionment of representation. The motion came from a New England member. Many years afterward, the question was put to Madison in a Virginian assemblage, but he preserved silence. It remains among the curious mysteries of that historic convention which have never been cleared up. A plausible explanation is furnished in a pamphlet entitled, "The Lost Principle," published at Richmond on the eve of the Civil war.[1] The anonymous writer argues that "$\frac{3}{5}$" was chosen in order to preserve the equilibrium of the sections; that the South would never have consented to it on any other plea. If the negro at the south were counted as a whole man and not as three-fifths of a man, the slave-holding states would possess a clear majority in the first electoral college.

The balance became apparent in the census of 1790. The population of the northern states was found to be 1,977,000; that of the southern states, 1,952,000. The admission of Vermont, Kentucky and Tennessee established a perfect balance in the senate — eight slave-holding states and eight free states, making up the union at the beginning of the century.

Federalism and Anti-Federalism proved a transitory issue — the great fact of sectionalism asserting itself with a dominant earnestness, after Hamilton had broken with Madison; and after the pregnant controversy of the Secretary of State with the Secretary of the Treasury, across the council boards of Washington's first cabinet. It had cropped out even in the selection of that cabinet; it came forth aroused at Hamilton's fiscal proposals; it manifested itself in southern objection to the admission of Vermont, and in northern objection to the admission of Kentucky. By the end of Washington's term, the lines were fully and sharply drawn; much to the distaste and displeasure of the father of his country, too. In his farewell address, he expresses serious concern that "ground should have been furnished for characterizing parties by geographical discriminations," regarding it as a serious disturbance to the union. Such discriminations appeared in a marked degree when the task of choosing his successor was reached. New England gave her solid vote to John Adams. The South cast six sevenths of her vote for Thomas Jefferson. Down to 1840, the same sectional proceeding was rehearsed in every presidential contest.

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[1] The Lost Principle, by Barbarrossa. Richmond, 1860. The author is supposed to be Robert Scott, of Virginia.

II.

It would be merely repeating familiar history to describe the frequent sectional clashes that ensued down to the eve of secession. Both north and south were thoroughly alive to the sectional bearing of every important question. Nobody doubts the statesmanship of the Louisiana purchase; yet that broad and praiseworthy stroke of patriotism was bitterly misliked at the time[1] and the hostility came wholly from New England, jealous of the chance for increased prestige which this new territory gave the south. The Hartford Convention of 1812, was the culmination of New England's anti-national feeling; open threats to "cut the connection" with the major part of the union and secret plottings to invite Canadian and British alliance are evidences of the rampant disunionism there prevalent. The South and the West never forgot the disloyalty of New England, during the war of 1812; and we see the force of reproach which that record had, in Haynes' debate with Webster, twenty years later. That famous debate, and the strained relation smoothed by the Missouri compromise in 1820, indicated how irrepressible a fact sectionalism had become.

Up to 1850, we have the phenomenon in our political history, which has been spoken of as "the twin birth of states." Every additional free state was followed by the admission of a slave state in order "to preserve the balance." The sectional leaders began looking anxiously to the future, and as the contest grew in intensity, the south bitterly chided itself for acquiescing in the ordinance of 1787, which forbade slavery in the northwest territory, and in the Missouri compromise of 1820, which shut out slavery north of the thirty-sixth parallel. The annexation of Texas and the Mexican war were distinctively southern measures, planned by the soured statesmanship of Calhoun, to redress the balance and give the south new room for more state-making. The northern Democracy came into the party convention of 1844, with a candidate and a platform adverse to the Texas policy of the south; but the south had its way. And at the same time, with the deliberate connivance of Calhoun, the United States receded from its position in the Oregon dispute with England. The forty-ninth parallel was accepted as our north-most boundary instead of 54° 40′; territory sufficient to carve out three northern states was needlessly surrendered to Great Britain in order to propitiate southern sectionalism. At the end Calhoun was badly deceived in the results expected from the Mexican war. These results eventually strengthened the free states, and gave them their final preponderance in the United States senate. The admission of California in 1850, placed the north one state in the lead for the first time since the days of Washington. The southern leaders began to perceive that the

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[1] "Twenty Years of Congress," by James G. Blaine, ch. 1, p. 14.

equilibrium of the sections was to be an impossibility in the future, and the plan of secession was broached as the ultimate sequel[1]

Webster, in his "7th of March speech," alleges that up to 1850, three-fourths of the places of honor under the United States government were held by southerners. Alexander Stevens, in his famous appeal against secession in 1860, drew the attention of his countrymen to the fact that since the beginning of the government the South had eighteen out of the twenty-nine justices of the Supreme court; sixty years of southern presidents to twenty-four of northern presidents; twenty-three out of thirty-five speakers of the House of Representatives; and eighty-six out of one hundred and forty foreign ministers. The South, as represented in the Senate, was thoroughly alert and determined to reject any appointees unfavorable to southern interests, or tainted with free soil convictions. Mr. Stevens challenged his fellow southerners to answer whether they could receive better treatment under any other government than they had under the Union, and whether they could compensate themselves for the loss of an advantageous partnership in any greater degree of influence and patronage.

III.

The South went out of the Union in 1860 not to preserve slavery, but in the disappointment of sectional defeat. It was not the institution of slavery that was threatened, but its extension as an element in the increase of the southern system. Even upon the threshold of his administration, Abraham Lincoln wanted the south to understand that the national government did not propose to interfere with slavery where that condition was established; but he stood for the policy, that slavery was an evil which should be isolated and not extended. When Lincoln declared that the nation could not go on existing, half slave and half free, his meaning was against the strife of slave sectionalism and free soil sectionalism, competing for the new states, and maintaining an equilibrium of liberty and servitude. Secession was the southern alternative to sectional-equilibrium-destroyed. As soon as the south lost an equal share in the political partnership, she made up her mind to go out. Her proportional importance might be respected, and slavery might be let alone. But when fate had ordained that proportion to be less than an equal one, the traditional political self-esteem of the south rebelled.

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[1] Mr. Calhoun, in his speech of March 4, 1850, argues that the union was endangered by reason of a widespread discontent among the people of the southern section due to a feeling that "they cannot remain as things now are consistently with *honor* and safety in the Union"; and the "great and primary cause of this belief is in the fact that the *equilibrium* between the two sections in the government as it stood when the constitution was ratified and the government put in action has been *destroyed*.

What had destroyed the sectional equilibrium and made all the strenuous effort, the political finesse and the brilliant strokes of southern statesmen nugatory and impotent? The answer is: emigration.[1] Next to the fact of sectionalism, I conceive the phenomenon of nineteenth century emigration to America to be the most notable circumstance in our later history. It was greater numerically, than the vast barbarian migration that overturned the Roman empire. To my mind, it has wrought in the nation other important results besides the transformation of the sectional question, but if none other, that alone would have been enough. The belated colonization of America by Ireland and Germany gave the north her numerical preponderance in the census; enlarged her relative strength in the House of Representatives; filled the places in the east of the army of young men going west and then followed, in renewed waves of immigration, the western pioneers. Know-nothingism arose like the specter of the alarmed slave master — the ghost of selfish occupancy whether vested in human chattels or in the chattel of social, political and industrial machinery — but the hope of creating a sectarian instead of a sectional line of demarcation failed. This clever expedient of the southern Whigs was futile to withhold the inevitable end of the equilibrium. And when the task of crushing the rebellion was upon the nation, the foreign born soldier was also thrown into the scale against the South; thousands of naturalized citizens were drafted into a school of patriotism which made them irreproachably American, and thousands of the descendants of an earlier emigration, typified in generals like Sheridan and Rosecrans, were also important elements in the victory of the north. Had this emigration gone to the South it would undoubtedly have counted in a different solution of the problem. Historians would not be able to trace a direct connection between the potato rot in Ireland and the Emancipation Proclamation. The three or four million emigrants who destroyed the sectional equilibrium were tools in the hands of Providence. Yet there was nothing accidental in the fact that their weight was cast with the North and against the South. It could not have been otherwise.

John C. Calhoun, in his last great speech in the senate, delivered in the year of his death, 1850, sought to explain the waning strength of the South by deploring the fact that slavery was shut out of the territory north of the Ohio river and north of the 36th parallel. He also bewailed the influence of the existing revenue system which he conceived to result in attracting the emigrant population to the North and robbing the South of her capital. Under other conditions he thought that the South would have re-

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[1] The growth in the tide of immigration will appear from the following figures:

Immigrants,	1789 to 1820 (estimated)	250,000
"	1821 to 1830	143,439
"	1831 to 1840	599,125
"	1841 to 1850	1,713,251
"	1851 to 1860	2,598,214

Sixty per cent. of the immigration up to 1860 was Irish.

ceived her share of the emigration, and the census of 1850 would show a population in the slave states equal to that in the free states. Now the truth of the matter is that without the tariff, and with the fullest reign of squatter sovereignty, the result would not have been different. The North was destined to obtain the bulk of emigration in any event. The natural repulsion and antipathy between free labor and slave labor settled the question in advance. Slavery would have starved free labor out of the South, even had it sought entrance there. The peculiar civilization of the South gave the North all the advantages of development. Had southern leadership at the start been of the style of Jefferson Davis and Robert Toombs, rather than of the temperament and range of Madison and Jefferson, the lead which the South gained and held for sixty years could never have been. The natural growth of the country was against her equilibrium; but the traditions of a lofty statemanship kept her in the ascendant. It might have been foretold at the treaty establishing equilibrium of the sections in 1787 that unless emigration was to be shut out, as well as the importation of slaves, after 1807, the South was doomed to numerical inferiority.[1] Otherwise it was starting a nation with all the conditions of enlargement and progress, with healthy life currents and virile institutions in a race for the ascendancy with a nation already palsied by servitude and mortgaged in half its energies to an effete civilization. The ship which caught in its sails every breeze from over the Atlantic was bound, even against odds, to outstrip the slaver becalmed in a dead sea.

IV.

A table of the sectional electoral vote in the leading Presidential contests since 1796, will show that the war has had no effect on the animus of the sections. New England and the South are still at opposite poles. But a table of the apportionment of the electoral vote under the several censuses since 1790, will illustrate important changes. Classing Delaware as a southern rather than a middle state, our table indicates that the South cast nearly one-half of the vote of the electoral college at the beginning. She casts thirty-eight per cent. of the electoral votes under the census of 1880. The New England section had twenty-eight per cent. of the electoral vote in 1790; to-day she has less than ten per cent. of it. The middle section consisting of New York, Pennsylvania and New Jersey has declined much less than New England, and rather less than the South; while the West which cast a little more than one-fifth of the electoral vote when Abraham Lincoln was a candidate, now casts a third of the whole vote, and bids fair to cast almost half the vote which shall elect a president in 1924.

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[1] Draper (American Civil War, 1-446), puts this opinion in the mouth of the slaveholder; "The mistake with us has been that it was not made felony to bring in an Irishman when it was made piracy to bring in an African."

ELECTORAL APPORTIONMENT BY SECTIONS FROM 1790 TO 1890, WITH PERCENTAGES.

SECTIONS.	1790-1800		1800-1810		1810-1820		1820-30		1830-40		1840-50		1850-60		1860-70		1870-80		1880-90	
	Electors.	Per cent.	Electors.	Per cent.	Electors.	Per cent.	Electors.	Per cent.	Electors.	Per cent.	Electors.	Per cent.	Electors.	Per cent.	Electors.	Per cent.	Electors.	Per cent.	Electors.	Per cent.
New England	39	28	45	26	51	24	51	20	50	17	43	16	41	14	39	13	40	11	38	9½
Middle States	34	25	47	26⅓	62	30	72	29	80	29	69	25	69	24	66	21	73	20	75	19
Western States	......	......	......	......	7	3	24	10	33	12	49	18	62	23	95	30	115	31	135	33½
Southern States	66	47	84	47⅔	96	43	114	41	125	42	114	41	120	39	114	36	138	38	153	38
Total Electoral Vote	139	.....	176	......	217	......	261	......	288	.....	275	......	296	......	314	......	366	......	401	......

SECTIONAL DIVISIONS IN TEN LEADING POLITICAL CONTESTS, 1796–1884.

SECTIONS.	1796.		1800.		1824.		1828.		1840.		1844.		1856.		1860.		1876.		1884.	
	Jefferson. (Dem.)	Adams. (Fed.)	Jefferson. (Dem)	Adams. (Fed.)	Jackson and Crawford.	Adams and Clay.	Jackson. (Dem.)	Adams. (Whig.)	Van Buren. (Dem.)	Harrison. (Whig.)	Polk. (Dem.)	Clay. (Whig.)	Buchanan. (Dem.)	Fremont. (Rep.)	Breckenridge and Douglas.	Lincoln. (Rep.)	Tilden. (Dem.)	Hayes. (Rep.)	Cleveland. (Dem.)	Blaine. (Rep.)
New England	......	39	......	39	......	51	1	50	7	43	15	28	......	41	......	41	6	34	6	32
Middle States	14	20	20	14	42	30	48	24	......	80	62	7	34	35	3	66	44	29	45	30
Western States	......	......	......	......	7	17	24	......	5	33	26	23	28	38	......	73	15	103	15	120
Southern States	54	12	53	12	91	23	105	9	48	78	67	47	112	....	81	......	119	19	153	......
Total	68	71	73	65	140	121	178	83	60	234	170	105	174	114	84	180	184	185	219	182

In both tables Delaware is classed as a Southern State.

The admission of four new states to the Union will further tend to overthrow the old sectionalism. Dakota, with an area larger than any other political division except Texas, with a rapidly growing population, and with sufficient fertility to support three million people, has properly been divided into two states. Washington and Montana having passed the requirements respecting population, have come in as growing and influential states.

The effect of these new additions to the Union, so far as the historic sections are concerned, may be estimated as follows: In the electoral college—the southern system of states will have 156 votes; the northern system will have 270 votes.

In the Senate sixteen southern states will be represented by thirty-two seats; twenty-six states of the northern system will have fifty-two seats.

In the House of Representatives, the South will be entitled to some 120 congressmen; the North will be entitled to over 220 congressmen.

The most insurmountable political ascendancy is, of course, more probable in the United States Senate that elsewhere. Sectionalism throughout our entire political history has nowhere been better preserved. While the country has been broken up irrespective of Mason and Dixon's line in the House of Representatives, and while great states of the North have shifted their political allegiance with a reassuring spontaneity at Presidential elections, the Senate has always continued in a large sense a mirror of deep rooted geographical differences. With a brief and uncertain interval of doubt it has now been uninterrupted possession of the preponderant party of one section for nearly thirty years, and unless new and unforeseen events or issues arise, it bids fair to continue that political ascendancy for many years longer.

V.

The growth of the West has established a counter-balance to southern sectionalism, and the overthrow of slavery has tended to remove the essential difference between northern and southern civilization. Though the bitterness of the struggle for equilibrium has survived the war, there has been a growing recognition of the transformed condition of the problem. Bellicose politics have gone out, shirted in ridicule; ridicule which is the right medicine for all earnestness that outlives its purpose. And the imaginary danger from a solid South is apt to yield to some considerations:

1. It is perceived that the south is solid to-day rather for domestic than for national reasons; it is not a sectional caucus solidified for the purpose of gaining some contention against the other sections as it figured in ante-bellum days. It is rather a domestic problem which makes the South solid. The white man has grappled with the black bear; and he has no choice about letting go. The South is solid to save herself and not to domineer over the nation.

2. Sectionalism of a sort we must always have. We cannot escape it. Sectionalism which arrays the nation into two hostile camps and maintains an equilibrium of political power at the price of propagating slavery is deplorable; but that kind of sectionalism is fortunately destroyed; its causes blotted out; its chance of recurrence satisfactorily removed by the growth of the west, and the story of emigration. Sectionalism, which does not divide the nation into two geographical camps or into hostile civilization; but which may split it up into three or more congeries of states at issue on matters which do not go so deep as the long standing feud between Cavalier and Puritan is tolerable. And it is inevitable.

The sectionalism which makes the South solid to-day, or which may make its solidity a condition in the future, is to be looked upon as of this milder character. The west may furnish us, in the years to come, the most conspicuous phase of such sectionalism.

In fact, the issue of the late Presidential contest was said to aim at creating "a new sectionalism"—one that might cleave the country from north to south, and array the states into manufacturing and agricultural belts. A brief epoch of that kind of sectionalism might be wholesome in getting the nation away from its old partisan moorings, and casting overboard the effigies of a conflict that was well ended, if it had been ended quickly.

The question of Canadian annexation is a matter somewhat related to our sectional question. Following our system of government, an independent Canada would be a lesser United States speaking the same language, cherishing similar institutions and one with us in race and religion. Such a neighbor would be a powerful magnet of disintegration should the New England and Middle States, for instance, disagree with the South and West on any important issue, and be hopelessly out-voted in Congress. The commercial interests of these sections might draw them into an alliance with the Canadian Republic, ending in the setting up of a new confederacy. This, of course, is rather problematical, but it is often the unexpected that happens. Either we must annex Canada, or Canada will disintegrate us. And it may be a serious question whether it is not better to take her while she is young and tractable, rather than wait until antipathies in political feelings are too far generated to make union easy and agreeable.

It remains to be said that if, for the sake of a perfect Union, we would wish to have as little sectional feud in the future, as possible, we must be observant of the strict letter of the constitution and learn to admire it as warmly for the restraints it imposes on Federal power as for the functions it grants.[1]

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[1] Prof. Bryce (Am. Commonwealths, II., 693) believes that "the United States are no more likely to dissolve than if they were a unified republic like France or a unified monarchy like Italy." He notes "the growing strength of the centripetal and unifying orces"—in which there is no little danger.

A federal government attempting to do a great many things in a great many directions is sure to arouse warring interests and clashing influences. And in a country which reaches from the Atlantic to the Pacific and touches the tropics, and stretches out to the land of the midnight sun, all such interests and influences are more or less geographical and sectional.

ARTIFICIAL KEYS

TO THE

GENERA AND SPECIES OF MOSSES

RECOGNIZED IN LESQUEREUX AND JAMES'S MANUAL OF THE MOSSES
OF NORTH AMERICA;

BY CHARLES R. BARNES,

Professor of Botany in the University of Wisconsin, Madison, Wis.

INTRODUCTORY.

In the summer of 1886 I published a key to the genera of mosses recognized in the Manual of Lesquereux and James. From the demand which has exhausted a large edition of that key, I have felt that the object of its publication was reasonably attained, that it really was helpful to students of mosses. Although much misgiving was felt as to its accuracy a considerable use of it has revealed but one serious omission, and neither time nor its users have indicated to the author how it could be materially improved. It is therefore reprinted here with the few alterations which have seemed desirable.

But since there are no keys to the species even of the largest genera in the Manual, the novice, deserted after reaching the genus, is left almost as much bewildered as if he had not been led so far. I have therefore been induced to prepare keys to the species of all the genera.

The only plea for such work is its anticipated usefulness. I hope that it will stimulate some to undertake the study and collection of mosses who have heretofore been deterred by their helplessness in the determination of them without more expensive aids than the amateur usually possesses. An earnest student equipped with patience, some skill in dissection, a compound microscope and the Manual, ought to be able with the additional assistance of these keys to determine the names of most of the mosses which he can collect. Those which remain uncertain he can refer to those who possess the illustrations and exsiccati which are often indispensable for identification. I shall be disappointed if these keys do not encourage more to enter upon the study of this exceedingly interesting group of plants, which, with the Hepaticæ, are more neglected than any of which we now have accessible descriptions.

In constructing these keys, I have thought it wise to make few changes in the nomenclature or in the rank of species. Of many in the Manual neither the present names nor the autonomy can be maintained. The changes I have made are, with one exception (Dicranum fuscescens), confined to the two genera which have been revised since the appearance of the Manual in 1884, viz., *Sphagnum*, by M. Jules Cardot, of Stenay, France, and *Fissidens*, by the author. M. Cardot is now engaged in a revision of *Fontinalis* and *Dichelyma*, and I regret that his results have not yet been published, that they might be included in the present keys.

I have included in the keys all the new species known to me which have been published since the issue of the Manual and before 1890, when the relation of these could be ascertained from the descriptions and figures.

(It is worth nothing that a considerable number of new species are about to be published in the *Bulletin of the Torrey Botanical Club* and in the *Botanical Gazette.*) Two genera, *Eucladium* and *Merceya*,[1] have been indicated as new to North America. The former has been included in the key to genera. The relationship of the latter is so problematical that I have been compelled to omit it.

The number in bold-face type following the name of a genus in the key to genera refers to the page of this publication where the key to its species may be found. The other number, in ordinary type, is that of the page in the Manual where it is described. When there is only the latter the genus contains but one species. The number following the species (in the keys to species) is the same as it bears in the Manual.

It will be found in a number of cases that the keys contradict characters assigned in the Manual. I have not knowingly permitted such contradiction without having good reasons therefor, so that they must be considered as corrections, and not accidental. There may be mistakes among them; it is highly probable that there are some elsewhere. I should be glad to receive notice of errors or omissions from any who detect them.

My thanks are due to Mrs. Elizabeth G. Britton, for kind assistance in several points.

CHARLES R. BARNES.

UNIVERSITY OF WISCONSIN, *February* 8, 1890.

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[1] *Merceya latifolia* Kindberg: *Bull. Torr. Bot. Club* xvi (1889) 94.

ANALYTIC KEY

TO THE

GENERA OF MOSSES.

ORDER I.— **Sphagnaceæ.**

Capsule dehiscing by a deciduous operculum, peristome none, leaves composed of large hyaline cells, with intervening rows of small chlorophyllose ones.
Genus single . . . . **Sphagnum,** 12. **24.**

ORDER II.— **Andreæaceæ.**

Capsule dehiscing by four (rarely six) longitudinal slits.
Genus single . . . . **Andreæa,** 25. **26.**

ORDER III.— **Archidiaceæ.**

Capsule bursting irregularly, spores few and very large.
Genus single . . . . **Archidium,** 49. **28.**

ORDER IV.— **Bryaceæ.**

Capsule bursting irregularly (spores numerous) or generally dehiscing by a deciduous operculum, in the latter case usually furnished with a peristome. Leaves not sphagnoid.

Genera numerous as follows:

I. CLEISTOCARPI.— *Capsule without a deciduous operculum.*

A. *Green protonema persistent.*

Leaves ecostate.
  Capsule colorless . . . . . . **Micromitrium,** 37. **26.**
  Capsule colored . . . . . . **Ephemerum,** 37. **26.**
Leaves costate . . . . . . **Ephemerum,** 37. **26.**

B. *Green protonema not persistent.*

Margins of leaves flat or incurved.
Leaves lance-obovate to broad-ovate, not abruptly pointed . . . . . . **Physcomitrella**, 39.
Leaves linear-lanceolate to subulate or abruptly pointed.
Calyptra mitrate . . . . **Bruchia**, 45. **27.**
Calyptra cucullate . . . . **Pleuridium**, 43. **27.**
[**Astomum** may be sought here.]

Margins of leaves more or less revolute.
Capsule spherical . . . . . **Sphærangium**, 40. **27.**
Capsule short-pointed.
Calyptra mitrate . . . . . **Microbryum**, 45.
Calyptra cucullate . . . . . . **Phascum**, 41. **27.**

II. STEGOCARPI.—*Capsule with a deciduous operculum.*

A. ACROCARPI.—*Flowers and fruit terminating the stem, either the main shoot or a branch.*

1. *Mouth of the capsule naked.*

* *Leaf-cells isodiametric, at least above the middle of the leaf, often obscure.*

Lid imperfectly formed, persistent . . . . . **Astomum**, 51. **29.**
Lid perfect, deciduous.
Capsule immersed.
Leaves lamellose . . . . **Pharomitrium**, 100.
Leaves not lamellose, ciliate . . . . . **Hedwigia**, 152.
Leaves with a hyaline hair-point . . . . **Grimmia**, 134. **43.**
Capsule exserted, ribbed when dry.
Calyptra cucullate.
Pedicel very short, strongly twisted to the left when dry . . . . **Amphoridium**, 158. **46.**
Pedicel long, twisted to the right when dry . **Braunia**, 153.
Calyptra campanulate-mitrate, plicate, usually hairy . . . . . . **Macromitrium**, 178. **50.**
Calyptra long clavate-campanulate, not plicate nor hairy . . . . **Encalypta**, 180. **50.**
Capsule exserted, not ribbed when dry.
Lid conic, beaked.
Pedicel short . . . . **Calymperes**, 184. **50.**
Pedicel long . . . . **Gymnostomum**, 52. **29.**
Lid conic, beakless, or conic-subulate . . . **Pottia**, 100. **37.**

Lid convex or flattish, beaked.
Plants large (2 cm. +), leaves distichous . . **Eustichia,** 94.
Plants large, leaves pluriseriate, papillose.
Leaves linear-lanceolate, margins plane . **Anœctangium,** 54.
Leaves ovate-lanceolate, margins reflexed, hyaline at base . . . . **Barbula,** 115. **39.**
Leaves lingulate-lanceolate, margins revolute, three-fourths hyaline . . . . **Desmatodon,** 110. **38.**
Plants small, leaves broader, hair-pointed or cuspidate or serrate, not papillose . . . . . **Pottia,** 100. **37.**
Plants small or minute, leaves lance-subulate . **Anodus,** 96.
Lid long-clavate . . . . **Encalypta,** 180. **50.**

* * *Leaf-cells plainly elongated, distinct.*

Lid small, convex or short-conic, capsule microstome.
Leaves vertically inserted , . . . **Schistostega,** 188.
Leaves subulate, dentate . . . . **Bartramia,** 203. **53.**
Leaves broad, entire, calyptra enclosing capsule . . . . **Pyramidula,** 196.
Lid large (rarely small), capsule macrostome.
Capsule splitting at the middle . . . **Aphanorhegma,** 196.
Capsule dehiscing regularly above the middle, not covered by calyptra . . . . . **Physcomitrium,** 196. **52.**

2. *Mouth of the capsule furnished with a peristome.*

* *Peristome single.*

+ *Teeth articulate.*

++ *Teeth eight.*

Leaves thick, coriaceous . . . . . **Octoblepharum,** 91.

[**Orthotrichum** and **Ptychomitrium** (§ *Notarisia*) may be sought here.]

++++ *Teeth sixteen, calyptra mitrate.*

= *Calyptra plicate.*

Teeth cribrose, purple . . . . **Coscinodon,** 154. **46.**
Teeth filiform, trifid . . . . . . **Ptychomitrium,** 156. **46.**
Teeth approximate or connate in pairs.
Lanceolate to subulate, papillose . . . **Ptychomitrium,** 156. **46.**
Triangular-lanceolate, articles quadrate.
Basal leaf-cells linear, chlorophyllose . . . **Ulota,** 160. **46.**
Basal leaf-cells hexagono-rectangular, hyaline **Orthotrichum,** 164. **47.**
Teeth short, pale, fragile . . . . **Macromitrium,** 178. **50.**

═ ═ *Calyptra not plicate.*

Aquatic, floating.
Leaves distichous . . . . **Conomitrium**, 89. **34.**
Leaves pluriseriate . . . . . . **Cinclidotus**, 134.
Terrestrial.
Very small, gregarious.
Teeth broad, erose-truncate, hyaline . . **Brachyodus**, 98.
Teeth linear-lanceolate, deeply bifid . **Campylostelium**, 99.
Larger, above 1 cm. in height.
Leaf-cells small, quadrate or punctate, obscure.
Beak long-clavate . . . . **Encalypta**, 180. **50.**
Beak long or short, not clavate.
Teeth lanceolate, flat, subentire or cribrose or 2—3-fid to the middle . **Grimmia**, 134. **43.**
Teeth linear-lanceolate, 2—3-fid to below the middle, or cleft to the base into filiform segments . . . . **Rhacomitrium**, 147. **45.**
Leaf-cells large, very distinct, pedicel with a prominent apophysis.
Apophysis smaller than the capsule.
Leaves entire, obtuse . . . . . . **Dissodon**, 189. **51.**
Leaves serrate, acute or acuminate . **Tayloria**, 190. **51.**
Apophysis exceeding the capsule . . **Splachnum**, 193. **51.**

++ ++ ++ *Teeth sixteen, calyptra cucullate.*

═ *Leaves distichous.*

Leaves subulate . . . . **Distichium**, 93. **36.**
Leaves broader, with a prominent vertical wing . **Fissidens**, 81. **34.**

═ ═ *Leaves pluriseriate.*

¶ *Capsule unsymmetric, cernuous-inclined or arcuate.*

Teeth filiform-bifid from a membranous base . **Desmatodon**, 110. **38.**
Teeth irregularly lacerate or bifid to the middle or below.
Leaf cells not enlarged at the basal angles, roundish or quadrate above.
Lid long-beaked, leaves serrulate, peristome equaling half the capsule . . . . **Dichodontium**, 61. **30.**
Lid long-beaked, leaves crenulate or denticulate, peristome shorter . . . . . . **Cynodontium**, 59. **30.**
Lid short-beaked . . . . **Oreoweisia**, 58.
Leaf-cells not enlarged at the basal angles, oblong above, rectangular at base . . . **Dicranella**, 64. **30.**

  - Leaf-cells enlarged-quadrate at the basal angles, linear at base . . . . **Dicranum**, 67. **31.**
  - Leaf-cells of two kinds, in two or three layers **Leucobryum**, 90. **36.**
- Teeth bifid to near the base.
  - Lid conic, leaves subulate . . . . . **Trichodon**, 92. **36.**
  - Lid conic, leaves lanceolate . . . . . **Ceratodon**, 92. **36.**
  - Lid aristate, neck very long . . . . . **Trematodon**, 62. **30.**
- Teeth not cleft, short, irregular . . . . **Catoscopium**, 211.
- Teeth not cleft, cohering by their tips . . **Conostomum**, 207.
- Teeth not cleft, perforate.
  - Neck long, exceeding the capsule . . . **Trematodon**, 62. **30.**
  - Neck inconspicuous, plants small . . . **Discelium**, 188.
  - Neck inconspicuous, plants large . . . **Oreoweisia**, 58.
- Teeth not cleft nor perforate.
  - Lid with a short thick oblique beak . . **Oreoweisia**, 58.
  - Lid with a short slender oblique beak . **Cynodontium**, 59. **30.**

[**Mielichhoferia** and **Funaria** may be sought here.]

¶ ¶ *Capsule symmetric, pendulous on a flexuous pedicel.*

- Teeth bifid to the middle . . . . **Campylopus**, 77. **33.**
- Teeth bifid to the base, free . . . . . **Dicranodontium**, 77.
- Teeth bifid to the common membranous base.
  - Connivent and slightly twisted . . . **Desmatodon**, 110. **38.**
  - Erect, not twisted . . . . **Trichostomum**, 108. **38.**
- Teeth entire, short, plants minute . . . . . **Seligeria**, 96. **36.**

¶ ¶ ¶ *Capsule symmetric, erect.*

- Teeth bifid to the common membranous base.
  - Lid short, conic or beaked . . . . . **Desmatodon**, 110. **38.**
  - Lid elongated, conic. . . . . . . **Trichostomum**, 108. **38.**

[**Barbula** may be sought here.]

- Teeth deeply bifid or cleft to the base, free.
  - Leaf-cells small, not enlarged at the angles, oblong above . . . . **Dicranella**, 64. **30.**
  - Leaf-cells small, not enlarged at the angles, roundish or quadrate above . . . . . . **Cynodontium**, 59. **30.**
  - Leaf-cells small, enlarged-quadrate at the angles . **Dicranum**, 67. **31.**
  - Leaf-cells large, distinct . . . . . **Angstrœmia**, 63.
- Teeth cribrose, perforate or slightly cleft.
  - Leaf-cells enlarged-quadrate at the angles.
    - Capsule broad-pyriform . . . . . . **Blindia**, 98.
    - Capsule oval to sub-cylindric . . . **Dicranoweisia**, 57. **29.**

Leaf-cells not enlarged at the angles.
Teeth large, mostly cribrose.
Pedicel little exceeding the often hair-pointed leaves . . . . **Grimmia**, 134. **43.**
Pedicel long, leaves hair-pointed . . **Desmatodon**, 110. **38.**
Pedicel long, leaves not hair-pointed.
Leaves serrate just above sheathing base . **Eucladium.**[1]
Leaves entire or crenulate above . . **Didymodon**, 104. **37.**
Teeth small, often truncate or rudimentary.
Leaf margins involute above . . . . . . **Weisia**, 55. **29.**
Leaf-margins revolute or plane.
Leaves densely papillose in the upper part . **Didymodon**, 104. **37.**
Leaves not papillose . . . . **Pottia**, 100. **37.**
Teeth entire.
Capsule with a long, thick apophysis . . **Tetraplodon**, 191. **51.**
Capsule oval to subcylindric.
Not ribbed when dry.
Teeth short, leaves entire, narrow . . . **Weisia**, 55. **29.**
Teeth short, leaves serrate, broad . . **Syrrhopodon**, 185. **50.**
Teeth linear-filiform, connate at base . **Didymodon**, 104. **37.**
Teeth narrowly lanceolate, free . . **Dicranoweisia**, 57. **29.**
Ribbed when dry . . . . **Rhabdoweisia**, 58. **29.**
Capsule short-pyriform, turbinate when dry.
Teeth blunt . . . . **Seligeria**, 96. **36.**
Teeth acute . . . . **Blindia**, 98.
Capsule pyriform, not turbinate when dry.
Plants gregarious or subcespitose . . . **Entosthodon**, 199. **52.**
Plants in deep, compact tufts . . . **Mielichhoferia**, 214.
Capsule ovate-globose, lid obliquely long-beaked **Drummondia**, 160.
Capsule globose, lid beakless, small . . . **Bartramia**, 203. **53.**

++++++++ *Teeth thirty-two.*

Teeth cancellate . . . . **Barbula**, 115. **39.**
Teeth filiform or linear, almost terete, arising from a long or short basilar membrane.
Short, slightly, if at all, twisted.
Leaves subulate or lance-subulate from a broader base . . . . **Leptotrichum**, 105. **37.**
Leaves broader, lid elongated-conic . . **Trichostomum**, 108. **38.**
[**Barbula** *rigidula* will be sought here.]
Leaves broader, lid short-conic or short-beaked **Desmatodon**, 110. **38.**
Long, twisted to the left . . . . **Barbula**, 115. **39.**

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[1] *E. verticillatum*, Br. and Sch.: Renauld and Cardot: *Bot. Gaz.*, xiv, (1889), 99.

Teeth flat, not from a distinct basilar membrane.
  Cells of capsule linear-oblong . . . **Dicranodontium**, 77.
  Cells of capsule irregularly polygonal . . **Didymodon**, 104. **37.**

+— +— *Teeth not articulate.*

++ *Teeth four, solid.*

Capsule linear-oblong, stems long, conspicuous . . **Tetraphis**, 186. **51.**
Capsule ovate, stems very short . . . . . **Tetrodontium**, 187.

++ ++ *Teeth thirty-two or sixty-four.*

Calyptra cucullate, capsule symmetric or nearly so.
  Leaves undulate-crisped when dry, lamellæ few (2—8), straight . . . . **Atrichum**, 255. **60.**
  Leaves sub-tubulose at apex, lamellæ undulate or numerous . . . . **Oligotrichum**, 258. **61.**
Calyptra cucullate, capsule unsymmetric, arcuate incurved . . . . **Psilopilum**, 259.
Calyptra mitrate, densely hairy.
  Capsule not angular, teeth 32 . . . . . **Pogonatum**, 260. **61.**
  Capsule 4—6 angled, teeth 64 . . . . . **Polytrichum**, 263. **61.**

* * *Peristome double.*

+— *Capsule symmetric, erect.*

Teeth almost none, imperfect or rudimentary . **Macromitrium**, 178. **50.**
Teeth perfect, linear, revolute, capsule smooth . **Schlotheimia**, 179.
Teeth linear or filiform, dark red or purple, capsule ribbed and twisted . . . . **Encalypta**, 180. **50.**
Teeth broadly or narrowly triangular-lanceolate, pale, capsule ribbed, not twisted.
  Leaf-cells at base linear, chlorophyllose . . . **Ulota**, 160. **46.**
  Leaf-cells at base hexagono-rectangular, hyaline **Orthotrichum**, 164. **47.**
Teeth linear, contracted at articulations, capsule smooth, cylindric . . . . **Leptotheca**, 251.

+— +— *Capsule unsymmetric, inclined or oblique or pendulous.*

++ *Inner peristome a plaited cone.*

Pedicel thick, red, densely verrucose . . . . **Buxbaumia**, 267.
Pedicel very short, almost none . . . . . **Diphyscium**, 266.

++++ *Inner peristome a membrane, carinate or cut into sixteen segments; these sometimes separated by cilia.*

= *Cilia very short, rudimentary or none.*

Membrane entire, 16-carinate. . . . . . **Cinclidium**, 249. **60.**
Membrane latticed or cleft to the base into filiform, appendiculate segments.
Pedicel none or very short, leaves ecostate . **Fontinalis**, 268. **62.**
Pedicel distinct, sometimes long, leaves costate . **Dichelyma**, 272. **63.**
Membrane not cleft to the base.
Segments entire or interruptedly cleft along the middle line.
Shorter than the teeth or rudimentary . . **Funaria**, 200. **52.**
Equaling the teeth in length.
Leaves squarrose-recurved from the middle . **Paludella**, 213.
Leaves not squarrose.
Pedicel long.
Leaf-cells narrowly rhombic-hexagonal, tending to linear, leaves narrow . . . . . **Webera**, 215. **53.**
Leaf-cells and leaf broader . . . . . **Bryum**, 223. **55.**
Pedicel short, neck long . . . . . . **Zieria**, 240. **58.**
Far exceeding the teeth in length.
Pedicel long, leaf-cells large, pellucid . **Amblyodon**, 211.
Pedicel long, leaf-cells small, rectangular, chlorophyllose . . . . **Meesia**, 212. **53.**
Pedicel short, neck long . . . . . . **Zieria**, 240. **58.**
Segments bifid, divisions divaricate.
Leaves lanceolate to subulate, large . . . . **Bartramia**, 203. **53.**
Leaves lanceolate or broader, smaller . . **Philonotis**, 208. **53.**
Segments filiform, united by fours at their tips . **Timmia**, 254. **60.**

= = *Cilia present.*

Appendiculate.
Leaves lance-subulate, cells linear . . . **Leptobryum**, 215.
Leaves broader, cells rhombic-hexagonal . . . **Bryum**, 223. **55.**
Inappendiculate.
Capsule not ribbed when dry.
Leaves lanceolate, glossy, cells narrowly rhombic-hexagonal, inclining to linear . . . . . **Webera**, 215. **53.**
Leaves ample, soft, oblong, ovate to obovate or broader, cells round-hexagonal . . . . . **Mnium**, 241. **58.**
Leaves narrowly lanceolate, rigid . . **Rhizogonium**, 250.
Capsule ribbed when dry.
Oblong or elongated pyriform . . . **Aulacomnium**, 252. **60.**
Sub-globose . . . . **Philonotis**, 208. **53**

B. PLEUROCARPI. *Flowers and fruit lateral, in the axils of leaves.*
[**Fontinalis** and **Dichelyma** may be sought here.]

1. *Peristome single (rarely none), teeth eight or sixteen.*
[Species belonging to genera under " B * " *infra* may be sought here.]

Leaves distichous, with broad vertical wing . . **Fissidens**, 81. **34.**

Leaves pluriseriate.

  Entire.

    Ecostate, abruptly long-acuminate, cells quadrate except in costal region, distinct . . **Habrodon**, 296.

    Ecostate, cells linear or rhombic, obscure . . **Leucodon**, 287. **65.**

    Costate, short acuminate . . . **Clasmatodon**, 297.

    Costate, obtuse, teeth 8, red . . . . . **Cryphæa**, 275. **63.**

  Serrate, capsule emergent . . . . . . **Leptodon**, 278. **64.**

  Serrate to ciliate-dentate, capsule long-pedicelled . **Fabronia**, 294. **65.**

2. *Peristome double, the inner often imperfect.*

* *Segments none or short, or obscured by adhering to teeth.*

+— *Leaves papillose.*

Entire, ovate to ovate-lanceolate.

  Teeth ciliate-papillose . . . . **Leskea**, 301. **66.**

  Teeth not papillose . . . . **Anomodon**, 304. **66.**

Entire or cristate-serrate, obovate or spatulate **Pterigynandrum**, 288.

Spinulose-dentate to fimbriate (rarely entire) deltoid or round-ovate . . . . **Thelia**, 298. **66.**

Serrate, broadly ovate . . . . . . **Pterogonium**, 289. **65.**

+— +— *Leaves not papillose.*

Capsule straight.

  Segments bifid or adherent to the teeth.

    Plants small (1–2 cm.), capsules about 2 mm. **Pylaisæa**, 308. **67.**

    Plants large (4–6 cm.), capsules about 4 mm. **Cylindrothecium**, 310. **67.**

  Segments not bifid nor adherent.

    Leaves ecostate or obscurely bicostate . . . **Neckera**, 281. **64.**

    Leaves costate . . . . **Antitrichia**, 290. **65.**

Capsule curved or arcuate . . . . . . **Homalothecium**, 309. **67.**

* * *Segments not distinctly keeled, narrow.*

+— *Leaves costate.*

Cells roundish to oval-rhombic.

  Papillose [except in *Leskea pulvinata*].

    Stem and branch-leaves similar . . . **Leskea**, 301. **66.**

    Stem-leaves much smaller than branch-leaves **Anomodon**, 304. **66.**

Not papillose.

Annulus large, compound . . . . . . **Cryphæa**, 275. **63.**

Annulus none, leaf-cells minute, obscure . **Neckera**, 281. **64.**

Annulus none, leaf-cells large, distinct **Anacamptodon**, 296.

Cells linear or vermicular.

Annulus none . . . . **Neckera**, 281. **64.**

Annulus present . . . . **Antitrichia**, 290. **65.**

[**Cylindrothecium**, with leaves obscurely costate, may be sought here.]

+— +— *Leaves ecostate.*

Annulus none . . . . **Neckera**, 281. **64.**

Annulus present.

Leaf-cells quadrate at basal angles . . **Cylindrothecium**, 310. **67.**

Leaf-cells not quadrate at basal angles . . **Orthothecium**, 315. **68.**

* * * *Segments distinctly keeled, often broad.*

+— *Capsule symmetric, erect.*

[Species of **Hypnum** with erect or sub-erect capsules will be sought here.]

Leaves papillose.

Plants large, branches erect, dendroid . . . . **Alsia**, 279. **64.**

Plants long, pendent from trees, branches filiform **Meteorium**, 286. **65.**

Plants small, branches erect, julaceous . . **Myurella**, 300. **66.**

Leaves not papillose.

Leaves costate or ecostate, complanate, pseudo-distichous . . . . **Homalia**, 285. **65.**

Leaves ecostate, annulus large (none in *Cyl. Drummondii*).

Cells quadrate at basal angles.

Teeth hyaline margined . . . . **Platygyrium**, 307.

Teeth not hyaline margined . . **Cylindrothecium**, 310. **67.**

Cells not quadrate at basal angles . . **Orthothecium**, 315. **68.**

Leaves ecostate, annulus small, narrow . . . **Pylaisæa**, 308. **67.**

Leaves costate, plants dendroid . . . . **Climacium**, 313. **68.**

+— +— *Capsule unsymmetric, often arcuate.*

Leaf-cells large, calyptra mitrate.

Leaves mucronate or acute or acuminate . . **Hookeria**, 292. **65.**

Leaves obtuse . . . . **Pterigophyllum**, 293.

Leaf-cells small, calyptra cucullate . . . . **Hypnum**, 316. **68.**

[**Climacium** *Ruthenicum* will be sought here.]

ANALYTIC KEYS

TO THE

SPECIES OF MOSSES.

SPHAGNUM,[1] p. 12.

I. *Branches dimorphous, some divergent, some pendent; hyaline cells with fibrils.*

A. *Chlorophyllose cells near one face of leaf, triangular, triangular-elliptical or trapezoidal in transverse section.*

1. *Chlorophyllose cells on the ventral face of leaf; hyaline cells most convex on the dorsal face.*

a. *Branch leaves minutely fringed all around* . **S. Portoricense, 22.**

b. *Branch leaves not fringed.*

- Walls of hyaline cells adjoining chlorophyllose cells furnished with a fringe of rudimentary fibrils . . **S. Austini, 21.**
- Walls of hyaline cells adjoining chlorophyllose cells thickly papillose . . . . **S. papillosum, 20.**
- Walls smooth.
  - Cortical cells of stem fibrillose.
    - Chlorophyllose cells narrowly triangular or triangular elliptical . . . . **S. cymbifolium, 19.**
    - Chlorophyllose cells very large, equilateral-triangular . **S. affine**[2].
  - Cortical cells porose, not fibrillose.
    - Stem leaves broadest at base . . . . . . **S. acutifolium, 1.**

      [**S. Wulfianum** may be sought here.]
    - Stem leaves broadest in the middle . . . . . **S. molle, 13.**
    - Stem leaves broadest at apex . . . . . . **S. fimbriatum, 4.**
    - Stem leaves of almost equal breadth throughout **S. Girgensohnii,**[3] **3.**

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[1] See Cardot: Révision des Sphaignes de l'Amérique du Nord, in Bull. Soc. roy. de bot. de Belgique, XXVI.

[2] Renauld & Cardot: Rev. Bryol. 1885, p. 44. See also Cardot: Sphaignes d'Europe in Bull. Soc. roy. de bot. de Belgique, XXV, p. 51, pl. 2, fig. 9 and 10 and pl. 3, fig. 5.

[3] S. strictum Lindb.

2. *Chlorophyllose cells on dorsal face of leaf; hyaline cells most convex on ventral face.*

a. *Cortex of stem distinct.*

Stem leaves very broad above and strongly fimbriate . **S. Lindbergii, 7.**
Stem leaves broadest below.
  Branch leaves with narrow border . . . . . **S. tenellum, 18.**
  Branch leaves with broad border . . . . . **S. cuspidatum, 5.**
  Branch leaves not bordered . . . . **S. Garberi, 14.**

b. *Cortex of two layers of small cells, indistinct, or wanting* . . . . **S. intermedium, 6.**

B. *Chlorophyllose cells exposed on both faces or included, elliptic in transverse section.*

1. *Free on both faces.*

Cortex consisting of one layer of cells.
  Branch leaves ovate-acuminate . . . . . **S. subsecundum, 15.**
  Branch leaves round ovate . . . . . . **S. cyclophyllum, 23.**
Cortex of more than one layer of cells.
  Stem leaves large, rounded and fimbriate at apex, with narrow border below.
    Branch leaves large, strongly squarrose . . . **S. squarrosum, 8.**
    Branch leaves smaller, slightly squarrose at tips . . **S. teres, 9.**
  Stem leaves small, with broad border below . . . **S. laricinum, 16.**

[**S. Wulfianum** may be sought here.]

2. *Included.*

Branches in fascicles of 7 — 12 . . . . . . **S. Wulfianum, 10.**
Branches in fascicles of 3 — 5.
  Cortex of 2 or 3 layers, with few small pores or none . **S. rigidum, 11.**
  Cortex of 4 or 5 layers, pores numerous . . . **S. medium, Limpr.[1].**

II. *Branches uniform, solitary or in pairs; hyaline cells fibrillose; cortical cells usually in one layer, without pores.*

Stem and branch leaves alike, broadly obtuse, entire or erose at apex . . . . **S. Pylæsii, 26.**
Stem leaves oblong or obovate, branch leaves narrow, linear oblong . . . . **S. Fitzgeraldi, 25.**

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[1] Cardot: l. c., p. 5.

III. *Branches uniform, all arcuate-divergent; hyaline cells without fibrils, those of the branch leaves with one or two central rows of pores.*

Hyaline cells of branch leaves with 5—10 pores in one row, **S. macrophyllum, 27.**
Hyaline cells of branch leaves with 40–60 pores in two rows . . . . **S. Floridanum.**[1]

Of the species enumerated the following are reduced by M. Cardot: SS. medium, papillosum, Austini and affine are sub-species of S. cymbifolium; S. laricinum of S. subsecundum; S. squarrosum of S. teres; S. Girgensohnii of S. acutifolium. and S. cuspidatum of S. intermedium.

S. rubellum Wils. becomes a variety of S. acutifolium; S. Muelleri Schimp. is a synonym of S. molle; S. Mendocinum S. & L. of S. cuspidatum; S. sedoides Brid. of S. Pylæsii.

S. cyclophyllum is believed to be an immature state of S. subsecundum, but is retained in the Key.

ANDREÆA, p. 25.

Costa 0.
  Leaves incurved, minute, rotund-obtuse, deeply bi-ventricose . . . . **A. parvifolia.**[2]
  Leaves spreading or secund, acuminate, not ventricose **A. petrophila, 1.**
Costate.
  Costa vanishing below apex . . . . . . **A. rupestris, 2.**
  Costa excurrent . . . . **A. crassinervium, 3.**

MICROMITRIUM, p. 37.

Spores 63μ diameter, leaves serrate . . . **M. megalosporum, 1.**
Spores 25μ diameter, nearly smooth, leaves serrate above **M. Austini, 2.**
Spores a little smaller, papillose, leaves nearly entire . **M. synoicum, 3.**

EPHEMERUM, p. 37.

Leaves not costate . . . . **E. serratum, 1.**
Leaves costate.
  Costa ending below or at apex . . . . . . **E. cohærens, 6.**

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[1] Cardot: l. c., p. 22.

[2] Müller: *Flora* 1887. 219.

- Costa excurrent.
  - Seta short, capsule acutely beaked. . . **E. stenophyllum**, 7.
  - Seta 0, capsule blunt pointed.
    - Leaves gradually long-acuminate, slightly and irregularly serrate at apex . . . . . **E. crassinervium**, 2.
    - Leaves with a long hyaline spinulose arista . **E. spinulosum**, 3.
    - Leaves papillose both sides . . . . . **E. papillosum**, 4.
    - Leaves long-spinulose on both sides . . . . **E. hystrix**, 5.

SPHÆRANGIUM, p. 40.

- Leaves papillose on both faces . . . . . **S. Schimperianum**, 4.
- Leaves smooth or papillose on back.
  - Margins reflexed, plants triquetrous . . . **S. triquetrum**, 3.
  - Margins almost plane, plants round or tetragonal.
    - Lower leaves ecostate . . . . **S. rufescens**, 2.
    - Lower leaves costate . . . . **S. muticum**, 1.

PHASCUM, p. 41.

- Capsule sub-globose, apiculate.
  - Leaf margins plane or incurved, denticulate . **P. Carniolicum**, 1.
  - Leaf margins reflexed, quite entire . . . **P. cuspidatum**, 2.
- Capsule ovate- or oblong-lanceolate . . . . - **P. bryoides**, 3.

PLEURIDIUM, p. 43.

- Inflorescence paroicous.
  - Costa reaching the obscurely serrate apex . . **P. subulatum**, 1.
  - Costa excurrent into a smooth awl-shaped point . **P. Ravenelii**, 2.
- Inflorescence autoicous.
  - Upper leaves long subulate.
    - Entire except at apex . . . . **P. alternifolium**, 3.
    - Serrulate from middle upward . . . . . **P. Bolanderi**, 5.
  - Upper leaves abruptly short pointed . . . . . **P. Sullivantii**, 4.

BRUCHIA, p. 45.[1]

I. *Collum 0.*

- Seta very short . . . . **B. palustris**, 1.
- Seta exceeding capsule . . . . **B. Beyrichiana**, 5.

[**B. brevicollis** may be sought here.]

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[1] This key must be quite imperfect, since the figures are so few, descriptions so imperfect and specimens so inaccessible that it is impossible to ascertain the characters in many instances.

II. *Collum present.*

A. *Equalling sporangium.*

Spores papillose	**B. Bolanderi**, 4.
Spores pitted	**B. brevifolia**, 12.

B. *Shorter than sporangium.*

1. *Calyptra papillose.*

Leaves denticulate at apex	**B. Ravenelii**, 13.
Leaves denticulate all around	**B. Hampeana**, 14.

2. *Calyptra smooth.*

a. *Leaves papillose*	**B. Donnellii**, 9.

b. *Leaves smooth (subpapillose in* B. Sullivantii.)

i. *Costa not filling the narrowed point.*

Synoicous	**B. flexuosa**, 2.
Monoicous	**B. Sullivantii**, 3.

ii. *Costa broad above, filling point.*

Capsule immersed	**B. brevipes**, 11.
Capsule exserted.	
Leaves appressed	**B. Hallii**, 8.
Leaves spreading.	
Seta straight.	
Collum more than ½ spore case	**B. Texana**, 10.
Collum less than ½ spore case	**B. brevicollis**, 6.
Seta geniculate at middle	**B. curviseta**, 7.

ARCHIDIUM, p. 49.

Autoicous.	
Costa reaching to point of leaf	**A. Ohioense**, 1.
Costa often long excurrent	**A. Hallii**, 5.
Paroicous.	
Leaves serrulate	**A. tenerrimum**, 2.
Leaves quite entire.	
Cells oval or rhombic	**A. Ravenelii**, 3.
Cells quadrangular or quadrate	**A. longifolium**, 4.

ASTOMUM, p. 51.

Capsules often clustered (2–3), oblong-oval . . . **A. Ludovicianum**, 2.
Capsules solitary.
Orange, subglobose, leaves crispate when dry . **A. Sullivantii**, 3.
Orange, oval, leaves not crispate . . . . **A. nitidulum, var.** 4.
Brown, shining, ovoid, leaves not crispate . . **A. nitidulum**, 4.
Brown, globose, leaves crispate . . . . . **A. crispum**, 1.

GYMNOSTOMUM, p. 52.

Lid long remaining attached to columella, capsule thick-walled, with 6–8 rows of transversely elongated cells at the mouth . . . . **G. curvirostre**, 3.
Lid falling early, capsule thin-walled, with 3–4 rows of transversely elongated cells at mouth.
Plants 1–2 mm. high, lid conic . . . . **G. tenue**, 4.
Plants 5–10 mm. high, lid subulate, costa 24—35 μ wide at base with 2 guides [1] . . . . . . **G. calcareum**, 1.
Plants 1–7 cm. high, costa 70 μ wide at base, with 4–6 guides [1] . . . . **G. rupestre**, 2.

WEISIA, p. 55.

Inflorescence autoicous.
Teeth more or less perfect or none, capsule wrinkled lengthwise when dry . . . . **W. viridula**, 1.
Inflorescence dioicous.
Teeth large, lacunose and bifid, capsule 8-sulcate . **W. longiseta**, 2.
Teeth truncate, capsule not sulcate . . . . . **W. Wolfii**, 3.

DICRANOWEISIA, p. 57.

Leaf cells at base thick-walled, linear (1:6–10) . . **D. crispula**, 1.
Leaf cells at base thin-walled, rectangular (1:2–3) . . **D. cirrhata**, 2.

RHABDOWEISIA, p. 58.

Leaves minutely denticulate or entire; teeth filiform, smooth, fugacious . . . . **R. fugax**, 1.
Leaves coarsely dentate; teeth linear, obliquely crossed-striate . . . . **R. denticulata**, 2.

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[1] See explanation under Dicranum, p. 31.

CYNODONTIUM, p. 59.

Annulus very narrow and persistent or 0.
  Leaf cells conical- to spinous-mamillose.
    Teeth not papillose, seta straight . . . . . **C. Schisti**, 1.
    Teeth papillose, seta often arcuate when moist . **C. gracilescens**, 2.
  Leaf cells not mamillose, papillose over partitions . . **C. virens**, 4.
Annulus distinct, revoluble . . . . . . **C. polycarpum**, 3.

DICHODONTIUM, p. 61.

Costa vanishing below apex, seta yellow. . . . **D. pellucidum**, 1.
Costa percurrent, seta red . . . . **D. Canadense**, 2.

TREMATODON, p. 62.

Collum equalling or somewhat exceeding the oval-oblong
    sporangium . . . . **T. ambiguum**, 1.
Collum greatly exceeding the cylindric sporangium . **T. longicollis**, 2.

DICRANELLA, p. 64.

I. *Cells of the exothecium rectangular-quadrate; seta red; costa usually broad and indistinct below.*

A. *Leaves not sheathing, erect-spreading.*

Costa percurrent or excurrent.
  Annulus 0, peristome papillose.
    Capsule cernuous, curved . . . . **D. varia**, 6.
    Capsule erect, symmetric . . . . . . **D. rufescens**, 7.
  Annulus present, peristome not papillose . . . **D. parvula.**[1]
Costa ceasing within the apex, annulus large, simple . **D. debilis**, 8.

B. *Leaves, from a sheathing base, squarrose.*

Broad, obtuse . . . . **D. squarrosa**, 4.
Abruptly subulate.
  Capsule striate, substrumose, leaf apex entire . **D. Grevilleana**, 2.
  Capsule not striate nor strumose, leaf apex serrulate . **D. Schreberi**, 3.

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[1] Kindberg: *Bull. Torr. Bot. Club* xvi (1889) 91.

II. *Cells of the exothecium prosenchymatous; seta often yellow; costa narrow and well defined below.*

A. *Seta red.*

Leaves, from a sheathing base, squarrose	**D. crispa**, 1.
Leaves not sheathing nor squarrose.	
Mostly erect, capsule cernuous	**D. subulata**, 9.
Secund, capsule erect	**D. curvata**, 11.

B. *Seta yellowish.*

Capsule symmetric, erect	**D. Fitzgeraldi.**[1]
Capsule cernuous.	
Strumose	**D. cerviculata**, 5.
Not strumose	**D. heteromalla**, 10.

DICRANUM, p. 67.

In this genus the structure of the costa is of diagnostic value. It is either composed of similar cells (*homogeneous*), or composed of large parenchyma cells and small sclerenchyma cells (*stereïdes*). The large parenchyma cells ("Deuter" of Lorentz[2]: here translated *guides*) form a row (seldom double) in the middle of the costa, touching each other tangentially. They are comparatively large, but little thickened and either empty or starch-bearing.[3]

I. *Monoicous, stems radiculose only at base; costa long excurrent, homogeneous.*

Capsule erect, not strumose.	
Striate and furrowed when dry . . .	**D. hyperboreum** Müll.[4]
Neither striate nor furrowed when dry . . .	**D. fulvellum**, 1.
Capsule cernuous, strumose.	
Leaf cells not papillose, capsule oblong-cylindric .	**D. Starkei**, 2.
Leaf cells with papillæ over the partitions, capsules short ovate.	
Leaves falcate-secund	**D. falcatum**, 3.
Leaves spreading	**D. Blyttii**, 4.

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[1] Renauld & Cardot: *Bot. Gaz.*, xiii (1888) 197. pl. XIII.

[2] Pringsh. Jahrb. f. wiss. Bot., vi. 374.

[3] Cf. Limpricht: *Die Laubmoose*, p. 23.

[4] Barnes: MSS.; var. papillosum, Renauld & Cardot: *Bot. Gaz.* xiv. (1889). 91.

II. *Dioicous, stems sub-radiculose above, costa flat, equalling or broader than the 2—4-stratose lamina whose superficial cells are without chlorophyll, capsule erect, regular.*

Costa not furrowed at back, smooth . . . . **D. albicans**, 11.
Costa furrowed and toothed at back . . . **D. longifolium**, 10.

III. *Dioicous, stems radiculose (often densely), costa with median guides.*

A. *Capsule cernuous, more or less arcuate.*

1. *Leaf cells pitted.*

a. *Costa not reaching the apex, leaves transversely undulate.*

Leaf cells above elongated, smooth.
  Costa serrate on back, not lamellose.
    Capsules solitary (rarely 2), annulus 0 . . . **D. palustre**, 19.
    Capsules clustered, annulus large, simple . **D. Drummondii**, 22.
  Costa with serrate lamellæ.
    Capsules clustered, perichætial leaves differentiated **D. undulatum**, 23.
    Capsules solitary (?), perichætial leaves like others **D. dipteroneuron.**[1]
Leaf cells above isodiametric, irregular.
  Smooth at back . . . . **D. Schraderi**, 20.
  Papillose at back . . . . **D. spurium**, 21.

b. *Costa percurrent or excurrent, leaves not undulate.*

[**D. palustre** may be sought here.]

Guides in two rows . . . . **D. majus**, 18.
Guides in one row.
  Perichætial leaves abruptly subulate . . . **D. scoparium**, 17.
  Perichætial leaves gradually subulate . . . . . **D. Howellii.**[2]

2. *Leaf cells not pitted or faintly so.*

a. *Capsules cernuous, curved.*

i. *Leaves quite entire, subulate.*

Points very brittle and mostly broken . . . **D. fragilifolium**, 16.
Points not broken . . . . **D. elongatum**, 12.

ii. *Leaves entire, upper obtuse* . **D. Groenlandicum**, Brid.[3]

Lower cells rectangular (1:2–3) . . . . . **D. Miquelonense.**[4]

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[1] Müller: *Flora*, 1887. 221.

[2] Renauld & Cardot: *Bot. Gaz.* xiv (1889) 93, pl. XII.

[3] Syn. D. tenuinerve, Zett.—Renauld & Cardot: *Fl. Miq.* 42 (1888); *Bot. Gaz.* xiv. (1889) 99.

[4] Renauld & Cardot: *Fl. Miq.* 42 (1888); *Bot. Gaz.* xiv. (1889) 93, pl. XII.

iii. *Leaves serrulate.*

Upper cells very irregular.
  Weakly papillose over partitions, capsule not striped, **D. congestum**, Brid.[1] 13.
  Not papillose, capsule striped.
    Inner perichætial leaves obliquely truncate to a short serrate subula . . . . **D. Muhlenbeckii**, 14.
    Inner perichætial leaves narrowed to thong-shaped point . . . . **D. rhabdocarpum**, 15.
    Inner perichætial leaves rounded with a short subula, **D. sabuletorum.**[2]
Upper cells regular, quadratic . . . . . . **D. fuscescens**,[3] 13.

b. *Capsule erect, symmetric.*

Costa without stereïdes . . . . **D. strictum**, 5.
Costa with two stereïde bands.
  Lamina above of two layers.
    Margin and costa serrulate . . . . **D. fulvum**, 9.
    Entire, apex usually broken . . . . **D. viride**, 7.
  Lamina throughout of one layer.
    Upper cells rectangular and mamillose . . **D. montanum**, 6.
    Upper cells less regular, not mamillose . . . **D. flagellare**, 8.

D. leioneuron and *D. stenodictyon* of Kindberg, *Ottawa Nat.* ii (1889) 155 and *Bull. Torr. Bot. Club* xvi (1889) 92, are species of uncertain relations. I have not seen authentic specimens, and the descriptions are too meager to enable me to form any judgment.

CAMPYLOPUS, p. 77.[4]

I. *Costa smooth at back.*

A. *Auricles none.*

[**C. gracilicaulis** may belong here.]

Upper leaves with hyaline points . . . . . . **C. Henrici.**[5]
Upper leaves without hyaline points . . . . . . **C. Leanus**, 4.

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[1] *D. fuscescens* of Manual.

[2] Renauld & Cardot: *Bot. Gaz.* xiv (1889) 91, pl. XII.

[3] This is var. *longirostre* and var. *angustifolium* of Manual.

[4] The genus is greatly in need of revision, with a view to discovering differential structural characters of the leaves. The few figures and meager descriptions render the key uncertain in many points.

[5] Renauld & Cardot: *Bot. Gaz.* xiii (1888) 197, pl. XIV.

B. *Auricles present.*

No lamina except small colored auricles	**C. Hallii**, 5.
Lamina distinct.	
Perichætial leaves concolorous.	
Auricles brown.	
Deeply concave	**C. flexuosus**, 1.
Plane, decurrent	**C. Tallulensis**, 2.
Auricles whitish, large.	
Leaves serrulate at apex	**C. subleucogaster**, 7.
Leaves spinulose serrate at apex	**C. Donnellii**, 8.
Auricles dirty red	**C. augustiretis**, 11.
Perichætial leaves with hyaline points (may include 8 and 11 above)	**C. gracilicaulis**, 10.

II. *Costa scabrous or lamellose at back.*

Leaves with pellucid hair points	**C. introflexus**, 3.
Leaves not hair pointed.	
Alar cells round, lamina 0	**C. frigidus**, 6.
No auricles	**C. Virginicus**, 9.

FISSIDENS, p. 81 (*incl. Conomitrium, p.* 89.[1])

I. (EUFISSIDENS.) *Plants terrestrial or submersed but not floating; leaves soft, of one layer of cells.*

A. *Fruit terminal.*

1. *Monoicous, male flowers axillary.*

Leaf-cells small, densely chlorophyllose, in distinct rows	**F. limbatus**, 5.
Leaf-cells larger, not densely chlorophyllose, nor in distinct rows	**F. bryoides**, 2.

2. *Dioicous or monoicous with the male flowers terminal on a rooting branch at the base of the female stem.*

a. *Leaf-cells $1\frac{1}{2}$–2 times as long as wide, large, distinct.*

Plants less than 1 mm. high, leaves two or three pairs	**F. Closteri**, 1.
Plants 2–4 mm. high, wholly hyaline, leaves 3–5 pairs	**F. hyalinus**, 9.

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[1] See Barnes: *Bot. Gaz.* xii (1887) 1.

b. *Leaf-cells almost or quite isodiametric, often obscure.*

- Leaves with a narrow border, at least on vaginant lamina.
  - Marginal leaf-cells not papillose . . . . . . **F. incurvus**, 3.
  - Marginal leaf-cells papillose.
    - Costa percurrent . . . . **F. Ravenelii**, 13.
    - Costa ceasing below apex . . . . **F. Garberi**, 15.
- Leaves without a border.
  - Acute, cells densely chlorophyllose, obscurely papillose **F. Donnellii**, 14.
  - Obtuse, cells pellucid, operculum conic . . **F. obtusifolius**, 17.
  - Apiculate, operculum with acicular beak . . **F. osmundoides**, 18.
- Leaves with a thick reddish border. Plants submersed, rigid . . . . **F. rufulus**, 8.[1]

B *Fruit lateral.*

1. *Leaves without a border.*

- Obtuse, entire, plants 2–5 cm. high, fruit sub-terminal **F. polypodioides**, 23.
- Rounded at apex, irregularly serrate, 1–2 cm. high, fruit sub-basal . . . . **F. sub-basilaris**, 22.
- Mucronate, regularly serrulate, fruit basal or sub-basal **F. taxifolius**, 20.

2. *Leaves bordered by several rows of paler, often incrassate, cells.*

- Capsule cernuous, leaf-cells minute . . . . . **F. Floridanus**, 7.
- Capsule erect or inclined, flowers dioicous, leaf-cells obscure . . . . **F. decipiens**, 19.
- Capsule erect or inclined, flowers monoicous, leaf-cells distinct . . . . **F. adiantoides**, 21.

II. (PACHYFISSIDENS.) *Leaves rigid, composed of more than one layer of cells, opaque.*

- Plants growing in water or very wet places . . **F. grandifrons**, 24.

III. (OCTODICERAS.)[2] *Plants aquatic, filiform, floating.*

- Plants large, much branched, pedicel shorter than the capsule . . . . **F. Julianus**, C. 1.
- Plants small, little branched, pedicel longer than the capsule . . . . **F. Hallianus**, C. 2.

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[1] *F. ventricosus*, Lesq.

[2] *Conomitrium* of Manual.

In the Revision of N. A. species of Fissidens,[1] FF. inconstans, exiguus and minutulus were reduced to F. incurvus, the two latter forming varieties. FF. bryoides var. cæspitans, crassipes, Hallii and Texanus are relegated to the list of doubtful species.

Two species have recently been named by Renauld and Cardot[2] as occurring in the U. S., *FF. Bambergeri* Schimp. and *viridulus* Wahl. The first of these I regard as a form of F. incurvus; the second is possibly a sub-species of the same. It may be known by its thin-walled capsule, with the peristome inserted below the mouth. Neither are worthy of a distinct place in the key.

LEUCOBRYUM, p. 90.

Capsule apparently lateral (by innovations), leaves erect-spreading, oblong lanceolate	**L. vulgare,**[3] **1.**
Capsule exactly terminal, leaves squarrose, very short and very broad	**L. sediforme, 2.**

CERATODON, p. 92.

Stems 2–3 (sterile often 10) cm. long, teeth articulate for $\frac{3}{4}$ length	**C. purpureus, 1.**
Stems 5 mm. long, teeth articulate to middle . . .	**C. minor, 2.**

TRICHODON, p. 92.

Cells of leaf base linear, above rectangular . . .	**T. cylindricus, 1.**
Cells of leaf base rectangular (1:2–4), above quadrate .	**T. flexifolius.**[4]

DISTICHIUM, p. 93.

Capsule erect, spores 17–20 μ	**D. capillaceum, 1.**
Capsule cernuous, spores 30–44 μ	**D. inclinatum, 2.**

SELIGERIA, p. 96.

Seta straight when moist.

Leaves sharp-pointed, cells above rectangular, spores 10–14 μ	**S. pusilla, 1.**
Leaves blunt-pointed, cells above quadratic, spores 14–18 μ	**S. calcarea, 2.**

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[1] See Barnes: *Bot. Gaz.* xii (1887) 1.

[2] *Bot. Gaz.* xiv (1889), 99.

[3] *L. minus* cannot be separated. L. vulgare varies from 3 to 20 cm. in height and good fruit can be found in the same tuft from December to August.

[4] Renauld & Cardot: *Bot. Gaz.*, xiv, (1889) 94, pl. XIII.

Leaves mostly blunt-pointed, cells rectangular, spores 24–32 μ . . . . **S. tristicha, 4.**
Seta arcuate when moist . . . . **S. recurvata, 3.**

POTTIA, p. 100.

I. *Peristome 0 or rudimentary.*

Costa with 2–4 lamellæ above . . . . . . **P. cavifolia, 1.**
Costa not lamellate.
  Leaf-margins more or less revolute.
    Lid conic obtuse, spores echinate . . . . . **P. minutula, 2.**
    Lid rostellate, spores papillose.
      Calyptra smooth . . . . **P. truncata, 3.**
      Calyptra scabrous . . . . **P. Wilsoni, 4.**
  Leaf-margins plane or involute.
    Lid abruptly rostrate, leaves sharply serrate above . **P. Heimii, 5.**
    Lid conic, leaves distantly denticulate above . . **P. riparia, 6.**
    Lid conic-subulate, leaves slightly crenulate above . **P. Barbula, 7.**

II. *Peristome distinct.*

Leaves oblong-lanceolate, margins revolute . . . **P. Starkeana, 8.**
Leaves rounded or round-spatutate, margins plane . **P. latifolia, 9.**

DIDYMODON, p. 104.

Leaf cells throughout quadratic . . . . . . **D. luridus, 2.**
Leaf cells below rectangular.
  Leaf base reddish, margins above revolute . . . **D. rubellus, 1.**
  Leaf base hyaline, margins plane . . . . . **D. cylindricus, 3.**

LEPTOTRICHUM, p. 105.

Dioicous.
  Leaves slightly twisted.
    Stem leaves spreading, perichætial leaves hardly sheathing . . . . **L. tortile, 1.**
    Stem leaves imbricate, perichætial leaves long sheathing . . . . **L. vaginans, 2.**
  Leaves not twisted.
    Plants short (1–2 cm.), not radiculose . . . **L. homomallum, 3.**
    Plants long (to 10 cm.) densely radiculose . . **L. flexicaule, 4.**

- Monoicous.
  - Plants short (5 mm.)
    - Teeth cylindric, nodose-articulate, leaves spreading . **L. pallidum, 5.**
    - Teeth flattened, linear, trabeculate, perforate, leaves secund . . . . **L. Schimperi, 6.**
  - Plants longer (2–3 cm.), glaucous . . . . . **L. glaucescens, 7.**

TRICHOSTOMUM, p. 108.

I. *Lamina composed of one layer of cells, papillose.*

- Margin reflexed or undulate, entire.
  - Annulus 0 . . . . **T. tophaceum, 1.**
  - Annulus large, compound . . . . **T. pyriforme, 2.**
- Margin plane or incurved.
  - Costa reaching apex or excurrent; serrate above.
    - Base of leaf yellowish, with thick walled rectangular cells . . . . **T. crispulum, 3.**
    - Base of leaf hyaline.
      - Abruptly mucronate or obtuse, with long papillæ **T. flavo-virens, 4.**
      - Gradually acuminate, papillæ low . . **T. nitidum, Sch.**[1]
  - Costa ceasing far below apex; entire . . . **T. Coloradense.**[2]

II. *Lamina of two layers, upper surface mamillose, lower smooth.*

- Peristome not twisted, seta arcuate or variously bent . **T. flexipes, 5.**
- Peristone twisted, seta subflexuous . . . . . **T. anomalum, 6.**

DESMATODON, p. 110.

I. *Capsule erect or nearly so.*

A. *Leaves without a hyaline or thickened border.*

1. *Not papillose* . , . . **D. systilius, 2.**
2. *Papillose.*

a. *Costa excurrent into a hair.*

- Capsule oblong (1:2 or 1:3 excl. lid), 16 teeth divided nearly or quite to base.
  - Plants of mountainous regions; calyptra reaching base of capsule . . . . **D. latifolius, 1.**
  - Plants of lowlands; calyptra reaching half way to base of capsule . . . . **D .Guepini, 10.**

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[1] Renauld and Cardot: *Bot. Gaz.* xiv (1889), 99.

[2] Appendix, p. 413.

Capsule cylindric (1:5–6); teeth divided half way or entire.

[**D. obliquus** may be sought here.]

Dioicous . . . . **D. plinthobius, 6.**
Monoicous . . . . **D. Neo-Mexicanus, 7.**

b. *Costa vanishing at apex or forming a short point.*

Leaves hyaline ¾ of their length . . . . . **D. obtusifolius, 9.**
Leaves hyaline only at base.
  Margins revolute.
    Capsule long cylindric, leaves crenulate . . **D. arenaceus, 3.**
    Capsule elliptic, leaves entire . . . . . . **D. nervosus, 8.**
  Margins inflexed above . . . . **D. Garberi, 4.**

B. *Leaves with a pellucid border.* . . **D. Porteri, 5.**

II. *Capsule nodding or pendent.*

Leaves with a thickened border below.
  Seta straight, capsule nodding or horizontal . . **D. cernuus, 11.**
  Seta reflexed, capsule pendent . . . . . **D. Laureri, 13.**
Leaves without a border . . . . **D. obliquus, 12.**

BARBULA, p. 115.

I. *Leaves with jointed dichotomous filaments on the costa.*

Costa broad (½ leaf) flattened, leaves thick, rigid . . § **I. Aloidellæ.**
Costa narrow, round, leaves thin, broad . . . . § **II. Chloronotæ.**

II. *Leaves not filamentose.*

Teeth from a low membrane, scarcely projecting from the mouth [excl. *B. brevipes*].
  Plants small.
    Leaf cells distinct . . . . § **III. Cuneifoliæ.**
    Leaf cells small.
      Perichætial leaves little different from the foliage, § **IV. Unguiculatæ.**
      Perichætial leaves long sheathing or convolute . § **V. Convolutæ.**
  Plants robust [excl. *B. cæspitosa*].
    Leaves entire; stems radiculose . . . . . § **VI. Tortuosæ.**
    Leaves serrate, stems not radiculose . . . . § **VII. Squarrosæ.**
Teeth from a high tesselated membrane . , § **VIII. Syntrichiæ.**

§ I. Aloidellæ.

Synoicous . . . . **B. brevirostris**, 1.
Dioicous.
  Annulus broad, revoluble, calyptra reaching the middle of the capsule . . . . **B. rigida**, 2.
  Annulus small, persistent, calyptra barely covering the lid . . . . **B. ambigua**, 3.

§ II. Chloronotæ.

Leaves with hair points.
  Tip of leaf hyaline . . . . **B. membranifolia**, 4.
  Tip of leaf concolorous.
    Hair smooth, leaves acute or somewhat obtuse . **B. chloronotos**, 5.
    Hair serrate, leaves rounded obtuse . . . . . **B. Henrici.**[1]
Leaves without hair points . . . . **B. Manniæ.**[2]

§ III. Cuneifoliæ.

Leaves bordered by 2–4 rows of thickened cells . . **B. marginata**, 8.
Leaves bordered by 1 row of round yellowish cells with prominent papillæ, aristate . . . . . **B. Vahliana**, 7.
Leaves with a broad yellowish border, not pointed **B. Egelingi** Schliep.[2]
Leaves without a border.
  Costa excurrent into a hoary hair . . . . . **B. muralis**, 12.
  Costa forming a short point or ceasing below apex.
    Leaf cells smooth . . . . **B. cuneifolia**, 6.
    Leaf cells papillose [incl. *B. amplexa ?*]
      Peristome membrane long . . . . . . **B. brevipes**, 11.
      Peristome membrane short.
        Inner perichætial leaves short . . . **B. Bolanderi**, 9.
        Inner perichætial leaves long-sheathing, abruptly reflexed . . . . **B. amplexa**, 10.

§ IV. Unguiculatæ.

[**B. cæspitosa** may be sought here.]

I. *Peristome 0.* . . . . **B. rubiginosa**, 28

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[1] Rau: *Bull. Washb. Coll. Lab.* i (1886), 172.
[2] Müller: *Flora* 1887, 222.

II. *Peristome present.*

A. *Teeth straight or scarcely twisted.*

Nodose, separate . . . . **B. rigidula**, 22.
Cancellate . . . . **B. cancellata**, 19.

B. *Teeth plainly twisted.*

1. *Leaves blunt or mucronate by the excurrent costa.*

Leaves short, ovate, the very apex obtuse.
  Capsule cylindric, calyptra reaching middle . **B. brachyphylla**, 20.
  Capsule ovate, calyptra reaching base . . . **B. purpurea**, 21.
Leaves longer, narrower, sharp pointed.
  Cells at base rectangular and pellucid.
    Capsule oblong-elliptic to sub-cylindric, sub-incurved, **B. unguiculata**, 13.
    Capsule oblong, small, erect . . . . . . **B. Jooriana**, 14.
  Cells at base quadrate, chlorophyllose . . . **B. Cruegeri**, 18.

2. *Leaves gradually pointed.*

a. *Leaves not papillose* [incl. *B. artocarpa ?*]

Annulus none . . . . **B. gracilis**, 31.
Annulus large, simple, persistent . . . . . **B. artocarpa**, 30.

b. *Leaves papillose.*

i. *Cells at base roundish, quadrate or short-rectangular.*

Annulus 0.
  Costa 70 μ wide at base and tapering gradually . **B. fallax**, 15.
  Costa 50 μ wide, of equal breadth to middle . **B. recurvifolia**, 17.
Annulus pale, compound . . . . **B. elata**, 27.

ii. *Cells at base rectangular, often elongated.*

[**B. fallax** may be sought here.]

Leaves erect-incurved, imbricate when dry.
  Cells above 5–7 μ diameter . . . . . . **B. vinealis**, 23.
  Cells twice as large . . . . **B. virescens**, 25.
Leaves squarrose-spreading or reflexed, twisted when dry.
  Perichætial leaves open, sheathing only at base, revolute on edges . . . . **B. subfallax**, 16.
  Perichætial leaves half sheathing.
    Annulus simple, narrow, persistent . . . **B. semitorta**, 29[1].

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[1] In Lesq. & James' Manual, p. 126, in note under *B. semitorta*, read "Comparable to *B. vinealis*" instead of B. brachyphylla. See *Pacif. R. R. Rept.*, iv, 186.

Annulus double or triple.
Cells 5–7 μ in diameter . . . . . **B. cylindrica**, 26.
B. flexifolia, 24.
Cells twice as large . . . . **B. virescens**, 25.

Nos. 23, 24, 25, 26, with possibly 29, are doubtless forms of one species, so that the key will probably break down here.

§ V. Convolutæ.

Leaves involute on margin.
Aristulate by excurrent costa . . . . . . **B. agraria**, 34.
Acute or submucronate . . . . **B. Donnellii**, 36.
Leaves plane on margin or recurved.
Capsule costate when dry . . . . **B. Raui**, 35.
Capsule smooth.
Leaves acute, costa percurrent . . . . . **B. convoluta**, 32.
Leaves with hyaline point . . . . **B. Closteri**, 33.

§ VI. Tortuosæ.

Leaves long linear, acute, abruptly mucronate . . **B. cæspitosa**, 37.
Leaves very long acuminate, cuspidate.
Twisted crispate when dry, above of one layer of cells **B. tortuosa**, 38.
Not crispate, brittle, two layers of cells above . . **B. fragilis**, 39.

§ VII. Squarrosæ.

Includes but one species . . . . **B. squarrosa**, 40.

§ VIII. Syntrichiæ.

[**B. brevipes** may be sought here.]

I. *Leaves with a border of thickened cells.*

Marginal cells elongated . . . . **B. subulata**, 41.
Marginal cells roundish . . . . **B. lævipila**, 44.

II. *Leaves not bordered.*

Cells smooth . . . . **B. mucronifolia**, 43.
Cells papillose.
Monoicous.
Costa percurrent . . . . . **B. inermis**, 42.
B. subulata var. mutica, 41.
Costa excurrent into a long (mostly smooth) hyaline hair . . . . **B. lævipila**, 44.

- Polygamous, costa excurrent into a hyaline spinulose hair **B. Muelleri, 48.**
- Dioicous.
  - Costa percurrent or ceasing below apex . . . **B. latifolia, 45.**
  - Costa short-excurrent, clothed above with gemmæ **B. papillosa, 47.**
  - Costa naked, excurrent into a hyaline, spinulose hair.
    - Hair red at base, upper leaves acute . . **B. megalocarpa.**[1]
    - Hair white throughout, upper leaves rounded or emarginate . . . . **B. ruralis, 46.**

GRIMMIA, p. 134.

- Seta shorter than the capsule.
  - Straight, capsule symmetric.
    - Lid falling with columella . . . . . . **§ I. Schistidium.**
    - Lid persistent on columella . . . . . . **§ II. Scouleria.**
  - Crooked, capsule ventricose . . . **§ III. Gasterogrimmia.**
- Seta longer than capsule.
  - Arcuate . . . . **§ IV. Eugrimmia.**
  - Straight . . . . **§ V. Guembelia.**

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§ I. Schistidium.

- Leaves with hyaline points (excl. vars. of 1 and 3)
  - Perichætial leaves obtuse, in lower ⅔ cells large . **G. platyphylla, 4.**
  - Perichætial leaves hair pointed.
    - Capsule oblong . . . . **G. ambigua, 2.**
    - Capsule ovate-globose.
      - In small dense cushions, soft, lurid green . **G. conferta, 1.**
      - In lax cushions, coarse, fuscescent . . . **G. apocarpa, 3.**
- Leaves muticous.
  - Margins plane.
    - Coarsely dentate at apex . . . . **G. Agassizii, 5.**
    - Entire at apex . . . . **G. maritima, 6.**
  - Margins recurved or revolute . . . . . $\left\{\begin{array}{l}\textbf{G. conferta}\\ \textbf{G. apocarpa}\end{array}\right\}$ **vars.**

§ II. Scouleria.

Includes but one species . . . . **G. Scouleri, 7.**

§ III. Gasterogrimmia.

- Peristome 0, lamina bistratose near apex . . . . **G. anodon, 8.**
- Peristome present, lamina unistratose throughout . **G. plagiopoda, 9.**

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[1] Kindberg: *Bull. Torr. Bot. Club*, xvi (1889), 92.

§ IV. Eugrimmia.

Capsule costate when dry.	
Leaves homomallous-falcate when dry . . .	**G. hamulosa**, 12.
Leaves spirally twisted on stem when dry . .	**G. torquata**, 13.
Leaves incurved-cirrhate when dry	**G. contorta**, 11.
Leaves imbricate or slightly twisted when dry.	
Hair point rough, capsule obscurely costate .	**G. Muhlenbeckii**, 14.
Hair point smooth, capsule strongly costate.	
Laxly pulvinate-cespitose, dioicous . .	**G. trichophylla**, 16.
Densely pulvinate, monoicous	**G. pulvinata**, 10.
Capsule not costate (or obscurely) when dry.	
Leaves falcate-reflexed when moist	**G. Watsoni**, 15.
Leaves not reflexed.	
Margins plane, capsule elliptic, collum 0	**G. Olneyi**, 17.
[**G. Muhlenbeckii** may be sought here].	
Margins reflexed.	
Capsule subpyriform, collum distinct, leaves not gemmiferous	**G. Californica**, 18.
Capsule oval-oblong, upper leaves gemmiferous	**G. Hartmani**, Sch.[1]

A sterile species, *Grimmia arcuatifolia*, probably belonging to this section has been described by Kindberg in *Bull. Torr. Bot. Club*, xvi (1889), 93. It resembles G. Watsoni in the reflexed leaves.

§ V. Guembelia.

Lamina above 2–4-stratose.	
Calyptra cucullate.	
Leaves hair pointed	**G. commutata**, 25.
Leaves not hair pointed, rather blunt	**G. unicolor**, 28.
Calyptra mitrate.	
Leaf margins plane	**G. leucophæa**, 22.
Leaf margins recurved.	
Walls of basal cells sinuate	**G. Pennsylvanica**, 22.
Walls of basal cells smooth	**G. ovata**, 21.
Only the margin 2—4-stratose.	
Leaves muticous or hyaline, apiculate . .	**G. Coloradensis**, 20.
Leaves hair pointed.	
Annulus 0.	
Calyptra mitrate, covering whole capsule .	**G. calyptrata**, 23.
Calyptra cucullate	**G. montana**, 26.

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[1] Mrs. E. G. Britton, *Bull. Torr. Bot. Club*, xvi (1889), 340.

Annulus present.
  Cells of leaf base elongated (1:4 to 1: 8) . . **G. Donniana, 19.**
  Cells of leaf base short (1:2) . . . . . **G. alpestris, 27.**

Grimmia Manniœ, apparently of this section, is described by Müller (*Flora* 1887, 223), from California. Mrs. E. G. Britton is of opinion that it is only *G. alpestris* Schleich.

RHACOMITRIUM, p. 147.

I. *Branches fastigiate.*

Leaves with a short hyaline point . . . . . **R. Sudeticum, 5.**
Leaves muticous.
  Costa with 2–4 lamellæ at back . . . . . . **R. patens, 1.**
  Costa not lamellose.
    Leaves with large quadrate cells at the basal angles, decurrent . . . . **R. depressum, 3.**
    Leaves not auricled nor decurrent.
      Obtuse.
        Perichætial leaves costate, seta long . **R. aciculare, 2.**
        Perichætial leaves ecostate, seta short . . **R. Nevii, 4.**
      Acute . . . . **R. Macounii,** [1].

II. *Branches fasciculate.*

A. *Leaves muticous.*

Cells elongated above. . . . . **R. fasciculare, 7.**
Cells quadratic above . . . . **R. varium, 8.**[2]
[**R. canescens** may be sought here.]

B. *Leaves with a hyaline point.*

Cells linear throughout lamina . . . . . **R. microcarpum, 9.**
Cells quadratic above.
  Strongly papillose both sides . . . . . . **R. canescens, 11.**
  Smooth (except at the point).
    Hyaline point denticulate . . . . . **R. heterostichum, 6.**
    [**R. canescens** var. **lutescens** and **R. varium** may be sought here.]
    Hyaline point strongly erose-serrate and papillose **R. lanuginosum, 10.**

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[1] Kindberg: *Bull. Torr. Bot. Club*, xvi (1889), 93.

[2] R. Oreganum Renauld and Cardot: *Bot. Gaz.*, xiii (1888), 198, pl. XV, is this species (*fide* J. Cardot *in litt.*), which seems to be *R. canescens*, var. *lutescens* L. and J.; *fide* Mrs. E. G. Britton *in litt.*

COSCINODON, p. 154.

Costa not entering the hyaline point which is less than the leaf in length.
Dioicous, leaves oblong lanceolate . . . . . **C. pulvinatus, 1.**
Autoicous, leaves obovate . . . . **C. Raui, 3.**
Costa forming a rough hyaline point twice as long as the leaf . . . . **C. Wrightii, 2.**

PTYCHOMITRIUM, p. 156.

Plants large (3 cm. +), leaves acuminate, sharply dentate **P. Gardneri, 1.**
Plants small (1 cm. —), leaves not acuminate, nearly or quite entire.
Collum 0.
Teeth subulate (1:10), entire . . . . **P. incurvum, 2.**
Teeth lanceolate (1:4), bi- or trifid . . . . **P. Drummondii, 3.**
Collum equalling one-third sporangium . . . . **P. pygmæum, 4.**

AMPHORIDIUM, p. 158.

Leaf margins plane, entire . . . . **A. Lapponicum, 1.**
Leaf margins recurved or revolute.
Leaves remote, recurved-spreading, serrate . **A. Sullivantii, 4.**
Leaves close.
Costa excurrent, seta arcuate . . . . . **A. Californicum, 3.**
Costa vanishing below apex.
Entire . . . . **A. Mougeotii, 2.**
Serrulate . . . . **A. cæspitosum, 5.**

ULOTA, p. 160.

I. *Leaves rigid, not crispate when dry.*

[**U. Drummondii** may be sought here.]

Costa percurrent . . . . **U. Hutchinsiæ, 9.**
Costa ceasing below apex . . . . **U. Barclayi, 10.**

II. *Leaves crispate when dry.*

Upper leaves tipped with gemmæ . . . . **U. phyllantha, 8.**

- Upper leaves not bearing gemmæ.
  - Dry capsule costate only at narrow mouth . . . **U. Ludwigii**, 2.
  - Dry capsule costate its whole length.
    - Stems creeping, leaves slightly crispate, peristome simple . . . . **U. Drummondii**, 1.
    - Stems not creeping, leaves strongly crispate, peristome double.
      - Mouth of capsule contracted . . . . . **U. Bruchii**, 4.
      - Mouth of capsule not contracted.
        - Tufts brown, on rocks . . . . . . **U. curvifolia**, 3.
        - Tufts green, on trees.
          - Capsule contracted below the mouth . . . **U. crispa**, 5.
          - Capsule not contracted below the mouth . **U. crispula**, 7.

U. Americana of Mitten (no. 6), is allied to the last two species, and I am unable to see wherein it differs in any features which can be used in a key.

ORTHOTRICHUM, p. 164.

I. *Leaves obtuse.*

- Margins plane, stomata superficial . . . . . **O. obtusifolium**, 31.
- Margins revolute.
  - Peristome simple, on rocks . . . . . . **O. Jamesianum**, 32.
  - Peristome double, in water . . . . **O. rivulare**, 30.

II. *Leaves with hyaline points.*

- Plants large (7–8 cm.) . . . . **O. Pringlei**, [1].
- Plants smaller (about 1 cm.).
  - Teeth equidistant, cilia of 1 row of cells . . . **O. diaphanum**, 28.
  - Teeth bigeminate, cilia of 2 rows of cells . . . . **O. canum**, 29.

III. *Leaves acute, without hyaline points, margins revolute or recurved.*

A. *Stomata superficial.*

1. *Peristome simple.*

[**OO. Texanum** and **rupestre** may be sought here.]

- Capsule wholly exserted, smooth when dry.
  - Defluent into seta . . . . **O. lævigatum**, 2.
  - Abrupt at base . . . . **O. Douglasii**, 6.

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[1] Müller: *Bull. Torr. Bot. Club.*, xiii (1886), 120. But July 18, 1888, he writes: "Mein O. Pringlei ist forma longifolia crispata papillosa von *O. Lyellii*, und anderer mal *O. papillosum* und *O. Pacificum* Hampe"!—*fide* Mrs. E. G. Britton.

- Capsule immersed or emergent.
  - Leaves densely papillose . . . . **O. Sturmii**, 4.
  - Leaves almost smooth . . . . **O. bullatum**, [1].

2. *Peristome double.*

[**OO. lævigatum** and **Sturmii**, may be sought here.]

a. *Capsule entirely smooth.*

- Immersed, papillæ simple . . . . **O. leiocarpum**, 25.
- Exserted, papillæ bifurcate . . . . **O. Kingianum**, 15.

b. *Capsule strongly costate.*

- Leaves beset with clavate gemmæ . . . . **O. Lyellii**, 33.
- Leaves not gemmiferous.
  - Teeth erect when dry, cilia 16 . . . . **O. Texanum**, 5.
  - Teeth reflexed when dry (O. brachytrichum ?), cilia 8.
    - Capsule (incl. collum) subcylindric.
      - Leaves acute, papillæ simple or bifurcate, salient . **O. affine**, 10.
      - Leaves apiculate, minutely papillose . . **O. brachytrichum**, 18.
    - Capsule obovate . . . . **O. sordidum**, 14.

c. *Capsule ribbed only near mouth.*

- Peristome opaque, very papillose, reflexed when dry **O. speciosum**, 12.
- Peristome opaque, transversely lineolate, reflexed when dry . . . . **O. Bolanderi**, 8.[2]
- Peristome not opaque, erect when dry, papillæ more or less obliterated or reduced to sinuous lines . . **O. rupestre**, 7.

B. *Stomata immersed.*

1. *Peristome simple.*

- Capsule smooth when dry . . . . **O. Douglasii**, 6.[3]
- Capsule faintly costate, bands (8, rarely 16) cinnamon-red **O. anomalum**, 1.
- Capsule 16-costate, bands (16, rarely 8) yellow . . **O. cupulatum**, 3.
- Capsule 8-costate . . . . **O. Texanum**, 5.[3]

[**O. Hallii** may be sought here.]

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[1] Müller: *Flora*, 1887, 223.

[2] This sp. is *O. rupestre*, var. *vulgare*, forma *densior* according to Venturi in Husn. *Musc. Gall.* 156.

[3] This species is repeated here because the character of the stomata is unknown to me.

2. *Peristome double.*

a. *Capsule smooth when dry.*

Cilia wider than teeth . . . . **O. exiguum, 24.**
Cilia narrow.
Capsule gradually narrowed to seta . . . . . **O. pallens, 26.**
Capsule abruptly contracted to seta . . . **O. psilocarpum, 23.**

b. *Capsule costate when dry.*

i. *Abruptly contracted to seta, collum not evident.*

Leaves with simple papillæ.
Capsule exserted, teeth papillose , . . . **O. consimile, 21.**
Capsule subimmersed, teeth with oblique sinuous lines . **O. Hallii, 13.**
Leaves rough with very long forked papillæ . . . **O. Watsoni, 9.**

ii. *Gradually narrowed to seta with evident collum.*

* *Capsule exserted.*

[**O. tenellum** may be sought here.]

Cilia 8, calyptra hairy . . . . . . **O. cylindricarpum, 22.**
Cilia 16, calyptra naked . . . . **O. pulchellum, 27.**

* * *Capsule immersed or nearly.*

Leaves with salient furcate papillæ.
Teeth papillose below, paler above, with longitudinal or sinuous lines, rarely perforate . . . . . **O. alpestre, 11.**
Teeth papillose throughout, often perforate along median line.
Neck of capsule shriveling into a cup which receives the seta, capsule contracted below mouth . . . **O. fallax, 17.**
Neck of capsule not becoming cupped, capsule not contracted below mouth . . . . **O. pumilum, Sw.**[1]
Leaves with simple, often weak papillæ.
Capsule emergent, subcylindric (long cyl. when dry), little contracted below the mouth . . . **O. tenellum, 20.**
Capsule immersed, obovate, contracted below mouth.
Neck shrivelling into a cup, which receives the seta . **O. fallax, 17.**
Neck not becoming cupped . . . . . **O. strangulatum, 19.**
Capsule immersed, not contracted.
Capsule straw-colored, teeth dirty-reddish . . **O. Ohioense, 16.**
Capsule with yellow (not orange) bands, teeth orange, yellow or pale . . . . **O. pumilum Sw.**[1]

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[1] Venturi: Husn. *Musc. Gall.* 179, pl. 49.

MACROMITRIUM, p. 178.

- Capsule plicate at mouth and base only . . . **M. Sullivantii, 1.**
- Capsule costate its whole length.
  - Lid conic, blunt, peristome 0. . . . . . **M. Fitzgeraldi, 2.**
  - Lid subulate, peristome present . . . . **M. rhabdocarpum, 3.**
- Capsule smooth . . . . **M. mucronifolium, 4.**

ENCALYPTA, p. 180.

I. *Capsule spirally striate and sulcate when dry.*

- Capsule twisted to the right when dry, leaves with hyaline hair points, teeth glabrous . . . . . **E. Selwyni, 7.**
- Capsule twisted to the left when dry.
  - Leaves acute or apiculate, teeth papillose, with a median line . . . . **E. procera, 6.**
  - Leaves muticous, usually obtuse, teeth filiform, nodose, minutely papillose . . . . **E. streptocarpa, 8.**

II. *Capsule vertically striate and sulcate when dry, or smooth.*

- Distinctly striate . . . . **E. rhabdocarpa, 3.**
- Smooth or faintly striolate.
  - Calyptra entire at base, peristome 0 or fugacious.
    - Calyptra smooth at apex . . . . . . **E. commutata, 1.**
    - Calyptra scabrous at apex . . . . . . **E. vulgaris, 2.**
  - Calyptra fringed at base, peristome present.
    - Leaves apiculate-acuminate . . . . . . **E. ciliata, 4.**
    - Leaves muticous . . . . **E. Macounii, 5.**

CALYMPERES, p. 184.

- Leaves oblong or broad-ovate.
  - Upper leaves very obtuse, often filamentose at apex . **C. Richardi, 1.**
  - Upper leaves acute, often filamentose in middle . **C. disciforme, 2.**
- Leaves narrowly panduriform, obtuse or retuse . **C. (?) crispum, 3.**

SYRRHOPODON, p. 185.

- Leaf margins bilamellate upwards . . . . . **S. Floridanus, 1.**
- Leaf margins single throughout . . . . . . **S. Texanus, 2.**

TETRAPHIS, p. 186.

Pedicel straight . . . . **T. pellucida, 1.**
Pedicel geniculate at middle . . . . . . **T. geniculata, 2.**

DISSODON, p. 189.

Seta short (5 mm.), thick, capsule erect, chestnut brown, **D. Hornschuchii, 1.**
Seta longer (1.5 cm.), plants 1–2 cm. high, capsule often inclined, orange . . . . **D. Froelichianus, 2.**
Seta longer (3–4 cm.), plants 4–12 cm., capsule erect, orange . . . . **D. splachnoides, 3.**

TAYLORIA, p. 190.

Teeth ½ length of sporangium, strap-like, reflexed, sinuous and twisted when dry, upper half of leaf serrate, **T. splachnoides, 2.**
Teeth much shorter, linear, recurved, upper third of leaf serrate . . . . **T. serrata, 1.**

TETRAPLODON, p. 191.

Leaves sharply serrate, narrowed to filiform point . **T. angustatus, 1.**
Leaves distantly incised-serrate, gradually acuminate . **T. australis, 3.**
Leaves entire, more or less abruptly filiform-apiculate.
  Costa sub-excurrent, empty sporangium constricted in middle . . . . **T. mnioides, 2.**
  Costa ceasing below point, empty sporangium not constricted in middle . . . . **T. urceolatus, 4.**

SPLACHNUM, p. 193.

Apophysis ovate or subglobose.
  About the size of the sporangium.
    Costa excurrent, apophysis red . . . . . **S. sphæricum, 2.**
    Costa ceasing below apex, apophysis at first green then brown . . . . **S. Wormskioldii, 1.**
  Greatly exceeding the sporangium . . . . **S. vasculosum, 3.**
Apophysis pyriform, exceeding the sporangium . **S. ampullaceum, 4.**
Apophysis campanulate.
  Purple . . . . **S. rubrum, 5.**
  Yellow . . . . **S. luteum, 6.**

PHYSCOMITRIUM, p. 196.

- Capsule immersed . . . . **P. immersum, 1.**
- Capsule exserted.
  - Leaves entire or nearly so.
    - Seta short, little exceeding leaves . . . . . **P. Hookeri, 4.**
    - Seta much longer (5–10 mm.)
      - Leaves ovate-lanceolate, collum distinct . **P. acuminatum, 5.**
      - Leaves linear-lanceolate, collum 0 . . **P. turbinatum, 6.**
  - Leaves serrate, cells at mouth of capsule transversely elongate.
    - 5–7 rows . . . . **P. pygmæum, 2.**
    - 12–15 rows [P. megalocarpum ?]
      - Leaves more or less acuminate, distinctly yellow-bordered . . . . **P. megalocarpum.**[1]
      - Leaves acute, not bordered . . . . . . **P. pyriforme, 2.**

ENTOSTHODON, p. 199.

- Leaves acute, capsule short-pyriform.
  - Costa percurrent, teeth dark red, striolate . . **E. Drummondii, 1.**
- Leaves acuminate, capsule long-pyriform.
  - Costa reaching middle, teeth whitish, granulose . **E. Bolanderi, 2.**
  - Costa subpercurrent, teeth red, nodose, papillose . **E. Templetoni, 3.**

FUNARIA, p. 200.

- Annulus 0.
  - Leaves entire or nearly.
    - Capsule arcuate, leaves acuminate
      - Costa excurrent . . . . **F. Americana, 1.**
      - Costa vanishing . . . . **F. Mediterranea, 2.**
    - Capsule erect, leaves acute . . . . . . **F. Californica, 5.**
  - Leaves sharply serrate.
    - Short-pointed, lid convex, mamillate . . . . . **F. serrata, 4.**
    - Long acuminate, lid short conic . . . . . **F. calcarea, 3.**
- Annulus large, revoluble.
  - Capsule irregularly plicate and furrowed.
    - Leaves with involute margins . . . . . . **F. convoluta, 6.**
    - Leaves with plane margins . . . . **F. flavicans, 7.**
  - Capsule distinctly striate-costate.
    - Leaves short-acuminate, lid large, spores 12–17 μ **F. hygrometrica, 8.**
    - Leaves long-acuminate, lid small, spores 24–28 μ **F. microstoma, 9.**

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[1] Kindberg: *Bull. Torr. Bot. Club*, xvi (1889,) 94.

BARTRAMIA, p. 203.

- Capsule erect, peristome 0 or simple.
  - Leaves reflexed on margin below, capsule rugose when dry . . . . **B. Menziesii, 1.**
  - Leaves plane, capsule plicate-furrowed . . . **B. subulata, 2.**
  - Leaves plane, capsule ribbed . . . . **B. stricta, 3.**
- Capsule curved, lid oblique, peristome double.
  - Seta short (= capsule), fruit pseudo-lateral . . **B. Halleriana, 7.**
  - Seta exceeding stems.
    - Leaves smooth . . . . **B. Œderiana, 5.**
    - Leaves papillose only on upper surface . . . . **B. radicalis, 8.**
    - Leaves papillose on both surfaces.
      - Base white, margin plane; synoicous . . **B. ithyphylla, 4.**
      - Base not white, margin revolute; autoicous . **B. pomiformis, 6.**

PHILONOTIS, p. 208.

- Leaf cells quadrate . . . . **P. Macounii, 2.**
- Leaf cells rectangular to linear.
  - Plants short (1–3 cm.).
    - Costa thick, rusty, leaves erect-spreading, capsule horizontal . . . . **P. Muhlenbeckii, 1.**
    - Costa canaliculate, leaves closely appressed, capsule oblique . . . . **P. Mohriana, 5.**
  - Plants usually long (3–15 cm.).
    - Mouth of capsule with 8 rows of transversely elongated cells . . . . **P. fontana, 3.**
    - Mouth of capsule with 4 rows . . . . . . **P. calcarea, 4.**

MEESIA, p. 212.

- Leaves entire, margins reflexed or revolute.
  - Synoicous, costa very thick ($\frac{1}{3}$ leaf base) . . . **M. uliginosa, 1.**
  - Autoicous, costa narrow ($\frac{1}{7}$ leaf base) . . . **M. Albertinii, 3.**
- Leaves entire, margins plane . . . . **M. longiseta, 2.**
- Leaves serrate . . . . **M. tristicha, 4.**

WEBERA, p. 215.

I. *Leaves with a reddish border, distinct to apex* . **W. Tozeri, 17.**

II. *Leaves not bordered, or indistinctly.*

A. *Annulus present.*

1. *Segments and cilia of endostome imperfect, often only a laciniate membrane* . . . . . . **W. camptotrachela.**[1]

2. *Segments of endostome not widely open along the keel, cilia 0 or short* (excl. *W. longicolla*).

- Inflorescence autoicous . . . . **W. acuminata, 1.**
- Inflorescence synoicous or dioicous.
  - Costa very broad, $\frac{1}{3}$–$\frac{1}{4}$ of leaf base . . . . . **W. Cardoti, Ren.**[2]
  - Costa narrow.
    - Plants less than 1 cm., seta 5–8 mm., capsule wide-mouthed when dry . . . . **W. nudicaulis, 11.**
    - Plants small, seta longer, mouth of capsule constricted when dry . . . . **W. Bolanderi, 12.**
    - Plants 2 cm. or more, seta 2–3 cm. . . . . . **W. cruda, 7.**
- Inflorescence paroicous.

  [**W. nudicaulis** may be sought here.]
  - Neck shorter than sporangium, cilia 0 . . . . **W. polymorpha, 2.**
  - Neck equaling sporangium, cilia more or less developed.
    - Cilia $\frac{1}{2}$ (or less) height of teeth . . . . . **W. elongata, 3.**
    - Cilia equaling teeth . . . . **W. longicolla, 4.**

3. *Segments of endostome split and gaping along keel, cilia well developed.*

- Inflorescence paroicous.
  - Capsule pendent, touching seta, not contracted under mouth . . . . **W. cucullata, 6.**
  - Capsule horizontal or pendent, not touching seta, contracted below mouth . . . . **W. nutans, 5.**
- Inflorescence dioicous.
  - Upper leaves lance-linear (1:8–10).
    - Plants loosely cespitose, in wet soil, 1 cm. high, seta 1–2 cm. . . . . **W. Lescuriana, 14.**
    - Plants solitary or gregarious, sphagnicolous, 3–6 cm., seta 3–4cm. . . . . **W. sphagnicola, 8.**
  - Uppermost leaves lanceolate (1:4–6).
    - Costa reaching apex . . . . **W. annotina, 9.**
    - Costa vanishing . . . . **W. commutata, 13.**

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[1] Renauld & Cardot: *Bot. Gaz.* xiii. (1888), 199, pl. XVI.

[2] Renauld & Cardot: *Bot. Gaz.* xiv (1889), 95, pl. XIII.

B. *Annulus 0.*

Leaves nearly entire, cilia very short . . . **W. Drummondii,** 10.
Leaves nearly entire, cilia 3 . . . . . . **W. Bigelovii,** 19.
Leaves sharply serrate.
  Stem red, leaves glaucous-green . . . . . **W. albicans,** 18.
  Stem and leaves green.
    Teeth red . . . . **W. carnea,** 15.
    Teeth yellow . . . . **W. pulchella,** 16.

BRYUM, p. 223.

Upper leaf cells rhombic to hexagonal.
  Plants not from stolons.
    Cilia 0, or inappendiculate . . . . . . **§ I. Cladodium.**
    Cilia 2–4, appendiculate . . . . **§ II. Eubryum.**
  Plants from stolons . . . . **§ III. Rhodobryum.**
Upper leaf cells linear (1:10–15) branches julaceous **§ IV. Anomobryum.**

§ I. Cladodium.

A. *Autoicous.*

Leaves broad (1:2), costa vanishing . . . **B. calophyllum,** 10.
Leaves ovate-lanceolate.
  Cilia long, smooth . . . . **B. Brownii,** 3.
  Cilia 0, or rudimentary.
    Capsule symmetric, pyriform, collum about ½ sporangium.
      Leaves faintly bordered, slightly revolute . . **B. Warneum,** 6.
      Leaves very distinctly bordered, broadly revolute **B. Biddlecomiæ,** 7.
    Capsule usually unsymmetric, elongate, collum = sporangium . . . . **B. uliginosum,** 11.

B. *Synoicous, or heteroicous.*

Costa long excurrent.
  Endostome attached to peristome.
    Spores verruculose . . . . **B. arcticum,** 1.
    Spores smooth, about 30 μ . . . . **B. pendulum,** 4.
    Spores smooth, scarcely 20 μ . . . . . . **B. augustirete,** [1].
  Endostome free[2] . . . . **B. inclinatum,** 5.
Costa short excurrent, or percurrent.
  Leaves not bordered . . . . **B. Knowltoni,** [3].

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[1] Kindberg: *Bull. Torr. Bot. Club*, xvi (1889), 94.

[2] *B. stenotrichum*, Müller (*Flora* 1887, 219), will be sought here and I am unable to discover from the description alone any essential difference between it and B. inclinatum.

[3] Barnes: *Bot. Gaz.* xiv. (1889), 44.

Leaves bordered.
  Teeth very short (scarcely 200 μ), articles 10–12 . **B. Labradorense**, [1].
  Teeth much longer, articles about 20.
    Costa excurrent, leaves reddish, margin scarcely revolute . . . . **B. purpurascens**, 2.
    Costa vanishing or barely excurrent, margin strongly revolute . . . . **B. lacustre**, 8.

[**B. flexuosum** may be sought here.]

C. *Dioicous.*

Endostome adherent to peristome, cilia 0 . . . **B. flexuosum**, 9.
Endostome free, cilia single . . . . . . **B. Californicum**, 34.

§II. Eubryum.

A. *Synoicous.*

Costa not excurrent . . . . **B. Oreganum**, 18.
Costa excurrent into a smooth point.
  Margins recurved . . . . **B. torquescens**, 16.
  Margins plane . . . . **B. microstegium** B. & S. [2].
Costa excurrent into a serrate point.
  Leaves short pointed, decurrent
    With a broad border . . . . **B. bimum**, 14.
    Without a border . . . . **B. lonchocaulon**, 15.
  Leaves long-cuspidate, not decurrent.
    Not bordered, entire . . . . . . **B. intermedium**, 12.
    Not bordered, serrate at apex . . . . . **B. provinciale**, 17.
    Bordered . . . . **B. cirrhatum**, 13.

B. *Autoicous.*

Capsule horizontal or nodding, leaf margins revolute . **B. pallescens**, 19.
Capsule pendulous, leaf margins plane . . . **B. subrotundum**, 20.

C. *Dioicous.*

1. *Costa not excurrent, or when excurrent forming a short point only.*

a. *Leaves obtuse.*

Distant, broadly ovate or oblong, rounded . . **B. cyclophyllum**, 35.
Imbricate, narrower.
  Dull olive green, margins strongly revolute . **B. Muhlenbeckii**, 26.
  Yellowish-green or purplish, tips of branches crimsoned.
    Cells polygonal, thick-walled . . . . . **B. miniatum**, 27.
    Cells rhombic, subquadrate below . . . . **B. Atwateriæ**, 28.

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[1] Philibert: *Revue Bry.*, 1887, 55.

[2] Renauld and Cardot: *Bot. Gaz.* xiv (1889), 99.

b. *Leaves pointed, costa percurrent or excurrent.*

i. *Capsule short* (1:2) *abrupt at base* . . . **B. atropurpureum**, 22.

ii. *Capsule longer* (1:3+) *tapering at base.*

* *Blood red to dark purple.*

Plant short (5–15 mm.) in small lax yellowish-green tufts . . . . **B. erythrocarpum**, 21.
Plants longer (3–5 cm.) in large compact shining red or purplish tufts . . . . **B. alpinum**, 25.

* * *Yellowish-brown.*

Slightly incurved.
  Constricted below mouth . . . . **B. meesioides** [1].
  Not constricted . . . . **B. pallens**, 36 .
Symmetric.
  Strongly constricted below mouth.
    Stems about 1 cm. high . . . . . . **B. turbinatum**, 39.
    Stems 4—10 cm. high. . . . . **B. Schleicheri**, 40.
  Slightly constricted below mouth.
    Leaf margins plane . . . . **B. Sawyeri** [2].
    Leaf margin revolute.
      Quite entire . . . . **B. acutiusculum** [3].
      Serrate at apex . . . . . . **B. pseudotriquetrum**, 38.

c. *Leaves pointed, costa vanishing.*

Leaves closely appressed, imbricate . . . **B. argenteum**, 29.
Leaves spreading, imbricate . . . . . . **B. capillare**, 31.
Leaves spreading, distant . . . . **B. Duvalii**, 37.

2. *Costa excurrent, leaves long-cuspidate.*

a. *Capsule short* (1: 2 *or less.*)

Constricted between sporangium and collum . . **B. versicolor**, 24.
Not constricted between sporangium and collum . **B. coronatum**, 23.

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[1] Kindberg: *Bull. Torr. Bot. Club*, xvi (1889), 95.

[2] Renauld and Cardot: *Bot. Gaz.*, xiv (1889), 95.

[3] Müller: *Flora*, 1887, 220.

b. *Capsule longer* (1: 3 +)

i. *Collum long* (½ *sporangium or more*).

Leaves strongly twisted when dry, abruptly pointed . **B. capillare**, 31.
Leaves erect and straight when dry.
  Collum equalling sporangium . . . . . **B. obconicum**, 33.
  Collum one-half the sporangium.
    Capsule constricted below the mouth . . **B. cæspiticium**, 30.
    Capsule not constricted . . . . . **B. Vancouveriense**, [1].

ii. *Collum short* (¼ *sporangium or less*). . **B. occidentale**, 32.

§III. Rhodobryum.

Costa percurrent or vanishing, margins revolute below, collum short . . . . **B. roseum**, 41.
Costa excurrent, margins revolute ⅔ to ¾, collum ½ sporangium, curved . . . . **B. Ontariense** [2].

§IV. Anomobryum.

Costa sub-excurrent . . . . **B. concinnatum**, 42.
Costa vanishing below apex . . . . **B. bullatum** [3].

Bryum hydrophyllum Kindberg[1] is a species "closely allied to B. pseudotriquetrum," but so imperfectly known (neither flowers nor capsule having been found), and so briefly characterized that I am unable to assign it to any place in the key.

ZIERIA, p. 240.

Costa vanishing, collum twice sporangium . . . . **Z. julacea**, 1.
Costa excurrent, collum = sporangium . . . **Z. demissa**, 2.

MNIUM, p. 241.

I. *Leaves serrate.*

A. *Teeth of leaves single.*

Stems dendroid . . . . **M. Menziesii**, 21.

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[1] Kindberg: *Bull. Torr. Bot. Club*, xvi (1889), 95.

[2] Kindberg: *Ottawa Nat.* ii (1889), 155 and l. c., p. 96.

[3] Müller: *Flora* 1887, 221.

- Stems simple or branched, not dendroid.
  - Basilar branches stoloniform.
    - Leaves acuminate, serrate to middle, lid convex or mamillate, membrane of endostome lacunose **M. cuspidatum, 1.**
    - Leaves acuminate, serrate to base.
      - Lid apiculate . . . . **M. medium, 4.**
      - Lid mammiform . . . . **M. affine, 7.**
    - Leaves rounded at apex, mucronate, lid rostrate . **M. rostratum, 6.**
  - Basilar branches erect, or stems simple.
    - Capsule warty-papillose at base . . . . . **M. venustum, 3.**
    - Capsule smooth at base.
      - Perichætial leaves entire . . . . **M. Nevii, 2.**
      - Perichætial leaves toothed.
        - Leaves nearly entire, not decurrent **M. affine, var. rugicum, 7.**
        - Leaves serrate to base, long decurrent . . **M. insigne, 8.**
        - Leaves serrate above, entire below.
          - Border distinct, yellowish brown . . **M. Drummondii, 5.**
          - Border 0 or faint . . . . . . **M. stellare, 16.**

B. *Teeth of leaves in pairs.*

- Costa vanishing just below apex . . . . **M. hornum, 9.**
- Costa percurrent.
  - Capsules solitary.
    - Synoicous . . . . **M. serratum, 10.**
    - Dioicous.
      - Leaf-cells small, about 15 μ[1] . . . **M. orthorrhynchum, 11.**
      - Leaf-cells larger (20–30 μ ?)[2] . . . . **M. lycopodioides, 12.**
      - Leaf-cells very large (50–60 μ ?)[3] . . . . **M. umbratile, 13.**
  - Capsules clustered.
    - Dioicous, leaves strongly crispate, capsule horizontal or inclined . . . . **M. spinosum, 14.**
    - Synoicous, leaves not crispate, capsule pendent **M. spinulosum, 15.**

II. *Leaves entire.*

- Upper leaf-cells with long diameters oblique to costa.
  - Leaves bordered.
    - Costate to apex, dioicous, capsule oblong . **M. punctatum, 18.**
    - Costa vanishing, synoicous, capsule subglobose **M. subglobosum, 19.**

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[1] *Fide* Husnot: *Musc. Gall.* 255.

[2] "Cellules un peu plus grandes," Husnot: *op. cit.*, 256. *M. riparium* Mitt. (*M. lycopodioides* Bry. Eu., *sec.* Mitten; *M. serratum* var. *riparium*, *sec.* Husnot, *l. c.*) has cells half as large as *M. umbratile* Mitt., *fide* Mitten: *Jour. Linn. Soc.* viii (1865), 30.

[3] Cells four times as large as M. orthorrhynchum, *fide* Mitten, *l. c.*

Leaves not bordered, costa vanishing, dioicous, capsule ovate-oblong . . . . **M. cinclidioides**, 17.
Upper leaf-cells isodiametric, costa vanishing **M. hymenophylloides**, 20.

CINCLIDIUM, p. 249.

Leaf margin of 4–5 rows of cells, laminal cells irregularly disposed . . . . **C. stygium**, 1.
Leaf margin of 2 rows of red cells, laminal cells in rows oblique to costa . . . . **C. subrotundum**, 2.

AULACOMNIUM, p. 252.

Leaves coarsely serrate to middle, autoicous . **A. heterostichum**, 5.
Leaves serrulate near apex, acute or acuminate, dioicous.
Stem leaves long acuminate, very roughly papillose **A. papillosum**, 4.
Stem leaves acute.
Stems commonly prolonged and gemmiferous, male flowers terminal, gemmiform . . **A. androgynum**, 1.
Stems not commonly gemmiferous, male flowers discoid . . . . **A. palustre**, 2.
Leaves entire, obtuse . . . . **A. turgidum**, 3.

[The leaves of **A. palustre** are entire when young, but soon become erose crenulate.]

TIMMIA, p. 254.

Capsule irregularly plicate when dry, segments appendiculate . . . . **T. Megapolitana**, 1.
Capsule costate at mouth when dry, segments not appendiculate . . . . **T. Austriaca**, 2.

ATRICHUM, p. 255.

Costa lamellose on upper side only.
Lamellæ 2–6, entire, lamina with teeth on surface.[1]
Lamellæ 4–6 cells high.
Leaves acute, serrate for ¾ length . . . **A. undulatum**, 1.
Leaves bluntish, serrate above middle only.
Teeth double, aculeate . . . . **A. augustatum**, 2.
Teeth single, short . . . . . . **A. xanthopelma**, 4.
Lamellæ 9–13 cells high . . . . **A. Selwyni**, 3.
Lamellæ 4–8, serrate . . . . **A. Lescurii**, 5.
Lamellæ 1–3, 1–3 cells high, lamina smooth . . **A. crispum**, 6.
Costa lamellose on both sides, lamina with longitudinal rows of teeth on back . . . . . . **A. parallelum**, 7.

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[1] Excluding A. xanthopelma?

OLIGOTRICHUM, p. 258.

Lamina and costa lamellose on both surfaces	**O. aligerum**, 1.
Costa only lamellose on upper surface	**O. Lyallii**, 2.

POGONATUM, p. 260.

I. *Plants simple, mostly short, leaves straight when dry.*

[**P. alpinum**, var. **simplex** will be sought here.]

Lamellæ with marginal cells smooth.	
Leaves entire	**P. brachyphyllum**, 2.
Leaves serrate	**P. brevicaule**, 1.
Lamellæ with marginal cells papillose.	
Teeth of leaves very long, often reflexed, marginal cells of lamellæ subquadrate	**P. dentatum**, 4.
Teeth moderate, 2 rows of marginal cells of lamellæ transversely rectangular	**P. capillare**, 3.

II. *Plants large* (4–15 *cm.*), *leaves twisted when dry.*

Leaves very long (1.5–2 cm.) short sheathing, lamellæ about 60	**P. Macounii.**[1]
Leaves less than 1 cm., short sheathing, lamellæ about 30 (?)[2], strongly contorted when dry	**P. contortum**, 5.
Leaves and lamellæ as in 5 (?) subcrispate, abruptly pointed	**P. atrovirens**, 6.

III. *Plants usually robust* (4–15 *cm.*), *rarely small, often much branched above, leaves straight when dry.*

Capsule papillose, marginal cells of lamellæ round in section	**P. urnigerum**, 7.
Capsule smooth, marginal cells of lamellæ ovate in section	**P. alpinum**, 8.

POLYTRICHUM, p. 263.

Leaves entire, margins inflexed.	
Obtuse at apex	**P. sexangulare**,[3] Flörke.

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[1] Kindberg: Polytrichum (Pogonatum) Macounii: *Bull. Torr. Bot. Club* xvi (1889), 96.

[2] As shown in *Sull. Icon. Musc. Suppl.*, pl. 42, ff. 5, 6.

[3] Kindberg: *Bull. Torr. Bot. Club* xvi. (1889), 96; Renauld & Cardot: *Bot. Gaz.*, xiv. (1889) 99.

Aristate at apex.
Awn colored, short.
Leaves spreading when moist, subrecurved . **P. juniperinum**, 4.
Leaves erect-open, strict . . . . . . **P. strictum**, 5.
Awn hyaline, long . . . . **P. piliferum**, 3.
Leaves serrate.
Marginal cells of lamellæ like rest, oval, higher than broad in section.
Capsule ovate, obscurely angled, lid rostrate . . **P. gracile**, 1.
Capsule oblong, 4–6 angled, lid acutely conic . **P. formosum**, 2.
Marginal cells of lamellæ enlarged, broader than high (2: 1) . . . . **P. Ohioense.**[1]
Marginal cells of lamellæ semilunar, with two prominent papillæ at corners . . . . . . **P. commune**, 6.

FONTINALIS, p. 268.

I. *Perichœtial leaves abruptly pointed, entire.*[2]

Leaves decurrent, teeth not lacunose . . . **F. Neo-Mexicana**, 3.
Leaves not decurrent, teeth lacunose . . . **F. Dalecarlica**, 4.

II. *Perichœtial leaves rounded-obtuse, entire or lacerate.*

A. *Leaves of branches unlike stem leaves* . . . **F. Howellii.**[3]

B. *Leaves homomorphous.*[4]

1. *Leaf-cells long-linear* (1: 10 +).

Alar cells very large.
Leaves acute . . . . **F. Sullivantii**, 8.
Leaves with very apex blunt or denticulate . . . **F. flaccida.**[5]

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[1] Renauld & Cardot: *Revue Bryol.* 1885, 11; also *Bot. Gaz.*, xiii, (1888), 199, pl. XVII.

[2] The fruit of *F. Californica* and *F. flaccida* has not yet been found. The latter will possibly fall here. Müller has also described imperfectly a sterile species, *F. maritima*, from Neah Bay, Wash. It is distinguished at once, he says, by the rigid branches and deeply carinate-canaliculate leaves. Having seen neither specimens nor figures I am unable to place it properly in the key.

[3] Renauld & Cardot: *Bot. Gaz.*, xiii (1888), 200, pl. XVIII.

[4] In *F. biformis* the summer leaves are unlike the vernal, so that specimens collected just as the vernal are falling might deceive.

[5] Renauld & Cardot: l. c., p. 201, pl. XIX.

- Alar cells moderately enlarged.
  - Capsule ovate to oblong.
    - Leaves crowded . . . . **F. Delamarei.**[1]
    - Leaves loose or scattered.
      - Perichætial leaves lacerate . . . . . **F. hypnoides, 11.**
      - Perichætial leaves entire, undulate at tip . . **F. Lescurii, 7.**
  - Capsule cylindrical.
    - 1: 4, endostome perfect . . . . **F. disticha, 10.**
    - 1: 5.5, endostome imperfect . . . . . . **F. filiformis, 9.**

2. *Leaf-cells rhombic-hexagonal* (1: 6 *or less.*)

- Plants shining with golden or coppery luster.
  - Stems robust, little branched . **F. antipyretica var. gigantea, 1a.**
  - Stems soft, much branched . . . . . . **F. Californica, 2.**
- Plants dull, yellowish to dirty green.
  - Leaves with one edge reflexed near base . . **F. antipyretica, 1.**
  - Leaves with margin plane.
    - Female flowers abundant, in most leaf axils . **F. Novæ-Angliæ, 6.**
    - Female flowers rare, at base of stems . . . **F. biformis, 5.**

DICHELYMA, p. 272.

- Costa percurrent or vanishing.
  - Capsule exceeding perichætium . . . . . . **D. falcatum, 1.**
  - Capsule not exceeding perichætium.
    - Seta longer than capsule . . . . . . **D. pallescens, 4.**
    - Seta shorter than capsule . . . . . . **D. subulatum, 5.**
  - [Capsule unknown] . . . . **D. Swartzii, 7.**
- Costa excurrent.[2]
  - Endostome a cancellate cone.
    - Seta about 1 cm. long, capsule oval . . . **D. uncinatum, 2.**
    - Seta 2—2.5 cm. long, capsule cylindric . **D. cylindricarpum, 6.**
  - Endostome of appendiculate cilia, united only at the tips . . . . **D. capillaceum, 3.**

CRYPHÆA, p. 275.

- Costa percurrent or excurrent.
  - Perichætial leaves costate . . . . **C. nervosa, 3.**
  - Perichætial leaves ecostate . . . . **C. inundata, 5.**

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[1] Renauld & Cardot: *Bot. Gaz.* xiv (1889), 96, pl. XIV.

[2] Here belongs a sterile species, *D. longinerve* of Kindberg (*Bull. Torr. Bot. Club* xvi (1889), 97, which has the basal cells of leaves "numerous, in 4-6 rows, subquadrate, the alar greater, pellucid." He is not sure whether it is a Dichelyma or a Hypnum (§ Harpidium)! In which case it would better have been left undescribed!

Costa vanishing near middle.
Costa of perichætial leaves excurrent into a thick point **C. glomerata,** 1.
Costa of perichætial leaves vanishing in or below apex . **C. pendula,** 2.
Costa of perichætial leaves vanishing far below apex . **C. Ravenelii,** 4.

LEPTODON, p. 278.

Leaves ecostate.
Leaf cells not pitted, capsule 2 mm. long . . **L. trichomitrion,** 1.
Leaf cells pitted, capsule 1 mm. long . . . **L. Floridanus,** 1a.
Leaves costate.
Leaf cells round-oval, capsule exserted, oblong-oval . **L. Ohioensis,** 2.
Leaf cells narrowly rhomboidal, capsule immersed, subglobose . . . . **L. nitidus,** 3.

ALSIA, p. 279.

Annulus 0.
Costa vanishing at middle (smooth ?), margins reflexed **A. Californica,** 1.
Costa vanishing near apex, dentate on back, margins plane . . . . **A. longipes,** 3.
Annulus compound, revoluble, leaves papillose at back . **A. abietina,** 2.

NECKERA, p. 281.

Leaves very obtuse
Plants slender (shoots 2 mm. wide), leaves loosely imbricate, rounded, concave . . . . **N. disticha,** 1.
Plants robust (shoots 4 mm. wide), leaves densely imbricate, truncate, not concave . . . . . . **N. undulata,** 2.
Leaves rounded, abruptly apiculate.
Revolute at base on one side, capsule immersed . **N. Menziesii,** 3.
Not revolute, capsule exserted . . . . . . **N. complanata,** 7.
Leaves acute or acuminate.
Ecostate or nearly so.
Capsule immersed or half exserted.
Shoots obtuse . . . . **N. pennata,** 4.
Shoots attenuate to apex.
Segments rudimentary, capsule immersed . **N. oligocarpa,** 5.
Segments as long as teeth, capsule ½ exserted . **N. Douglasii,** 6.
Capsule exserted . . . . **N. pumila,** 8.
Costate to the middle or beyond.
Margins broadly revolute . . . . . , **N. Floridana,** 9.
Margins not revolute.
Alar cells fawn-color, costa thin, percurrent . **N. Ludoviciæ,** 10.
Alar cells opaque, costa vanishing . . . **N. cymbifolia,** 11.

HOMALIA, p. 285.

- Costa vanishing above middle, leaves serrulate.
  - Leaves oblong, subfalcate, apiculate . . **H. trichomanoides**, 1.
  - Leaves lingulate, subfalcate, apiculate . . . **H. Jamesii**, 2.
- Costa sometimes hardly perceptible, leaves obovate, obtuse, serrulate . . . . **H. obtusata**, 3.
- Costa double, very short, or none, leaves entire . . **H. gracilis**, 4.

METEORIUM, p. 286.

- Leaves serrulate . . . . **M. pendulum**, 1.
- Leaves minutely crenulate . . . . **M. nigrescens**, 2.

LEUCODON, p. 287.

- Capsule exserted.
  - Leaves entire, open-erect, lid exactly conic . . **L. sciuroides**, 1.
  - Leaves serrulate at apex, squarrose, lid obliquely rostrate . . . . **L. julaceus**, 2.
- Capsule surpassed by perichætial leaves, leaves secund **L. brachypus**, 3.

PTEROGONIUM, p. 289.

- Leaves broadly oblong-ovate or -obovate, acute, smooth . **P. gracile**, 1.
- Leaves broadly deltoid-ovate, narrowly acuminate, papillose . . . . **P. brachypterum**, 2.

ANTITRICHIA, p. 290.

- Capsule oval (1:2—2.5), leaf cells fusiform . . **A. curtipendula**, 1.
- Capsule cylindric (1:6), leaf cells oval . . . . **A. Californica**, 2.

HOOKERIA, p. 292.

- Leaves bicostate to middle (not papillose?) . . . **H. varians**, 1.
- Leaves bicostate to apex, papillose . . . . . **H. cruceana**, 2.
- Leaves ecostate, entire (not papillose?) . . . . **H. Sullivantii**, 3.

FABRONIA, p. 294.

- Leaves ciliate-dentate.
  - Peristome of 16 teeth, costa 0 or very short . . . **F. pusilla**, 1
  - Peristome 0, leaves costate to middle . . **F. gymnostoma**, 2.
  - Peristome of 8 geminate teeth, leaves costate nearly to middle . . . . **F. octoblepharis**, 3.

Leaves serrate to subentire.
Sharply serrate, teeth orange, spores about 11 μ . **F. Wrightii**, 4.
Obscurely serrate, teeth brown, spores about 17 μ . **F. Ravenelii**, 5.
Obscurely serrate, teeth with prominent articulations on back . . . . **F. Donnellii**, 6.

THELIA, p. 298.

Papillæ of leaves simple.
Horn shaped, curved . . . . **T. hirtella**, 1.
Globose . . . . **T. robusta**, 3.
Papillæ 2—4-furcate.
Usually bi-furcate, teeth 1:17—20 . . . . . **T. asprella**, 2.
Usually 4-furcate, teeth 1:12 . . . . **T. Lescurii**, 4.

MYURELLA, p. 300.

Leaves serrulate, obtuse (rarely short apiculate) . . **M. julacea**, 1.
Leaves serrulate, abruptly apiculate-acuminate . . **M. apiculata**, 2.
Leaves spinulose-dentate, abruptly long acuminate . **M. Careyana**, 3.

LESKEA, p. 302.

I. *Costa reaching to or beyond the middle.*

Percurrent . . . . **L. nervosa**, 3.
Not percurrent.
Leaves entire.
Endostome divided into segments.
Cleft between articulations, leaves bluntish . . **L. obscura**, 2.
Not cleft, leaves acute . . . . **L. polycarpa**, 1.
Endostome a short undivided membrane . . . **L. Austini**, 6.
Leaves crenulate . . . . **L. tristis**, 5.

II. *Costa very short or none.*

Leaf cells linear-oblong . . . . **L. denticulata**, 4.
Leaf cells rhombic.
Leaves of primary stems acute . . . . . . **L. pulvinata**, 7.
Leaves of primary stems long acuminate . . . **L. Wollei**, 8.
Leaf cells round oval . . . . **L. nigrescens**[1].

ANOMODON, p. 304.

Leaves not papillose . . . . **A. Toccoæ**, 6.

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[1] Kindberg: *Ottawa Nat.* ii (1889), 155, and *Bull. Torr. Bot. Club* xvi (1889), 97.

Leaves papillose.
Base with large fimbriate-papillose auricles.
Margins reflexed near apex, replicate below middle **A. Californicus, 7.**
Margins not at all reflexed . . . . . . **A. apiculatus, 4.**
Base not auriculate.
Leaves filiform-acuminate . . . . . . **A. rostratus, 1.**
Leaves obtuse or apiculate:
Branches attenuate . . . . **A. attenuatus, 2.**
Branches not attenuate.
Leaves open-erect, teeth nodose . . . **A. obtusifolius, 3.**
Leaves secund, teeth not nodose . . . **A. viticulosus, 5.**

PYLAISÆA, p. 308.

Segments free, split below, leaves quite entire.
Plants glossy green . . . . **P. polyantha, 1.**
Plants pale yellowish green . . . . . . **P. heteromalla, 2.**
Segments free, split throughout, leaves serrulate at apex,
P. subdenticulata, 3.
Segments ½-adherent to teeth, spores 19—20 μ.
Leaves long-acuminate, margin not recurved . . **P. intricata, 4.**
Leaves short-acuminate, one or both edges recurved . **P. Selwyni,**[1]**.**
Segments wholly adherent, spores 28 μ . . . . . **P. velutina, 5.**

HOMALOTHECIUM,[2] p. 309.

Costa short, simple or forking, vanishing below middle.
Teeth red, operculum rostrate . . . . **H. subcapillatum, 1.**
Teeth yellow, operculum short apiculate . . . **H. corticolum,**[3]**.**
Costa narrow, vanishing in point . . . **H. pseudosericeum, 2.**

CYLINDROTHECIUM, p. 310.

Capsules clustered (3 or 4) . . . . **C. Floridanum, 4.**
Capsules solitary.
Plants densely pinnately branched, leaves muticous **C. concinnum, 8.**
Plants loosely pinnately branched, leaves pointed.
Gradually narrowly acuminate . . . . **C. brevisetum, 3.**

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[1] Kindberg: *Ottawa Naturalist* ii (1889), 156.

[2] Renauld & Cardot refer *Hypnum Nevadense* (30) to this genus. *Bot. Gaz.* xiii (1888) 202.

[3] Kindberg: l. c.

Acute or abruptly acuminate-apiculate.
  Almost entire, only alar cells quadrate or rectangular.
    Leaves acuminate-apiculate, teeth with 14—17 articulations, capsule 1: 3.5—4 . . . **C. cladorrhizans, 1.**
    Leaves abruptly short apiculate, teeth with 6—8 articulations, capsule 1: 5—5.5 . . . . **C. seductrix, 2.**
    Leaves not apiculate, teeth with 22—26 articulations, capsule 1: 2.5—3 . . . . . **C. compressum, 5.**
  Distinctly serrulate, all basal cells rectangular.
    Annulus 0, teeth obliquely striolate . . **C. Drummondii, 6.**
    Annulus large, teeth vertically striolate . **C. Sullivantii, 7.**

CLIMACIUM, p. 313.

Capsule straight, lid rostrate.
  Ovate-oblong (1: 2.5—3), leaves slightly decurrent and hollowed at basal angles . . . . . . **C. dendroides, 1.**
  Cylindric (1: 5—6), leaves long decurrent and broadly auriculate . . . . **C. Americanum, 2.**
Capsule arcuate, lid conic . . . . . . **C. Ruthenicum, 3.**

ORTHOTHECIUM, p. 315.

Leaves lanceolate, long and narrowly acuminate . . **O. rufescens, 1.**
Leaves exactly ovate, apex flexuous, not plicate . . **O. rubellum, 2.**
Leaves lanceolate to ovate lanceolate, plicate, not acuminate . . . . **O. chryseum, 3.**

HYPNUM, p. 316.[1]

I. *Leaves spreading.*

A. *Leaf cells short* (1: 3 *or less.*)

1. *Leaves papillose.*

a. *Paraphyllia present.*

i. *Costa obsolete* . . . . **H. dimorphum, 4.**

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[1] Nos. 2, 17, 18, 92, 93, 94, 114, 193, 194 and 195, are not included in this key. No. 2 is not North American, the locality cited by Schimper being York (Eng.), not *New* York. (Cf. A. Gepp in *Jour. Bot.* xxvii (1889), 152). The remainder are characterized by Lesquereux and James as of uncertain relationship or insufficiently known. No. 30 has been declared by Renauld and Cardot (*Bot. Gaz.* xiii (1889), 202), to be a Homalothecium, but is still given a place in this key.

ii. *Costa strong.*

* *Capsule oval or oblong, operculum convex-conic.*

Leaves entire . . . . **H. atrovirens**, 1.
Leaves serrulate at apex . . . . **H. radicosum**, 3.

* * *Capsule cylindric, or if oval-oblong then operculum long-rostrate* (excl. *H. gracile.*)

+ *Plants small* (*to* 5 *cm.*) *delicate, creeping,* 1—2-*pinnate.*

++ *Costa of stem-leaves wide* ($\frac{1}{6}$ *leaf-base.*)

Stems papillose . . . . **H. pygmæum**, 7.
Stems radiculose-tomentose . . . . **H. minutulum**, 6.

++ ++ *Costa of stem-leaves half as wide.*

Stem-leaves with long pellucid point, cilia 0 . . . . **H. erectum**, 9.
Stem-leaves short acuminate, cilia 2 . . . . . . **H. scitum**, 8.
Stem-leaves long acuminate, cilia 3 . . . . . **H. gracile**, 10.
Stem-leaves long acuminate, cilia 1 . . . . **H. calyptratum**, 11.

+ + *Plants large* (*to* 10 *cm.*), *creeping,* 2—3-*pinnate, forming extensive flat mats.*

Perichætial leaves long ciliate below.
Apical cells of branch-leaves not papillose, ovate, projecting . . . . **H. tamariscinum**, 12.
Apical cells of branch-leaves oblong, with 2—3 papillæ **H. delicatulum**, 14.
Perichætial leaves not ciliate, apical cells of branch leaves round . . . . **H. recognitum**, 13.

+ + + *Plants large* (*to* 10 *cm.*), *erect,* 1-*pinnate, in wide tufts.*

Capsule narrowly cylindric (1:5—6) . . . . . **H. abietinum**, 15.
Capsule oblong-cylindric (1:3) . . . . . . **H. Blandovii**, 16.

b. *Paraphyllia 0.*

Seta smooth.
Plants in large mats, leaves serrulate at apex, costate to middle . . . . **H. Brewerianum**, 66
Plants minute, leaves serrulate all round, costate to apex . . . . **H. leuconeurum**, 19.
Seta rough.
Stem leaves with hyaline piliferous point . . **H. ramulosum**, 21.
Stem leaves not hyaline pointed.
Perichætial leaves costate . . . . . **H. Whippleanum**, 20.
Perichætial leaves ecostate.
Bright green, leaves open, loosely imbricate . **H. laxifolium**, 23.
Dirty or yellowish green, leaves sub-falcate secund, closely imbricate . . . . . . **H. crispifolium**, 22.

2. *Leaves not papillose.*

a. *Shortly bicostate.*

Stem-leaves filiform-pointed . . . . . . **H. procurrens**, 5.
Stem-leaves not filiform-pointed.
Obscurely denticulate at apex . . . **H. leucocladulum**, 25.
Distinctly denticulate all around . . . **H. compressulum**, 26.

b. *Unicostate or ecostate.*

i. *Paraphyllia numerous, ciliate* . . . . . **H. paludosum**, 24.

ii. *Paraphyllia 0.*

* *Leaves coarsely serrate, plants dendroid.*

Branch leaves apparently 2-ranked, complanate . **H. Bigelovii**, 97.
Branch leaves equally spreading.
Perichætial leaves reflexed, dioicous.
Cilia of endostome equalling teeth . . . . . **H. Leibergii**[1].
Cilia short . . . . **H. neckeroides**, 96.
Perichætial leaves erect, heteroicous . . **H. Alleghaniense**, 95.

* * *Leaves entire, plants creeping.*

+– *Ecostate or with obscure traces of a nerve.*

Cilia 0.
Capsule constricted under mouth when dry . . **H. subtile**, 117.
Capsule not constricted . . . . . . **H. Sprucei**, 116.
Cilia 1—2.
Plants minute, filiform.
Leaves ovate, long acuminate . . . **H. confervoides**, 118.
Leaves long-lanceolate . . . . . . **H. minutissimum**, 115.
Plants large, in wide flat mats . . . . . **H. adnatum**, 124.

+– +– *Costate.*

++ *Leaves bordered with 4—5 rows of linear cells* **H. Lescurii**, 126.

++ ++ *Leaves not bordered.*

= *Plants in compact tufts 2—3 cm. deep* . . **H. compactum**, 125.

= = *Plants in loose mats or tufts.*

¶ *Costate to apex.*

Leaves acuminate.
Basal cells much enlarged . . . . . **H. irriguum**, 122.

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[1] Britton: *Bull. Torr. Bot. Club*, xvi (1889), 111.

Basal cells not enlarged.
Annulus triple . . . . **H. radicale, 120.**
Annulus simple . . . . **H. orthocladon, 121.**
Leaves not acuminate . . . . **H. fluviatile, 123.**

¶ ¶ *Costa ceasing above the middle.*

Cells alike throughout.
Inner perichætial leaves with a short (¼ length) point.
Capsule long-cylindric, arcuate, annulus triple . **H. serpens, 119.**
Capsule oblong, oblique, annulus simple . **H. Kochii** Br. & Sch.[1]
Inner perichætial leaves subuliform-acuminate, cells vermicular . . . . . . **H. porphyrrhizum** Lindb.[1]
Cells enlarged, rectangular at basal angles.
Cilia appendiculate, equalling segments . . **H. riparium, 127.**
Cilia rugulose, shorter than segments . . . **H. vacillans, 128.**

B. *Leaf cells elongated* (1:5 *or more*).

[**Amblystegium** spp. especially 127, 128 may be sought here.]

1. *Leaves costate half way or more.*

a. *Seta rough.*

i. *Leaves deeply plicate lengthwise.*

[**Brachythecium** spp. may be sought here.]

Plants regularly pinnate.
Seta scarcely equalling capsule . . . . . **H. Nuttallii, 29.**
Seta longer than capsule.
Perichætial leaves coarsely sinuate-dentate, cilia 0 **H. Nevadense,**[2] **30.**
Perichætial leaves entire or serrulate.
Stems erect, stout (to 15 cm.) . . . . . **H. megaptilum, 34.**
Stems prostrate.
Leaves with recurved, spinulose teeth . **H. hamatidens,**[3]**.**
Leaves serrulate.
Capsule oblong . . . . . **H. pinnatifidum, 31.**
Capsule long cylindric . . . . . **H. Amesiæ,**[4]**.**
Plants irregularly branched.
Leaves ovate-lanceolate (1:3) cilia 3, long as segments **H. æneum, 28.**
Leaves long-lanceolate (1:5) cilia 1 or 2, long or short **H. lutescens, 27.**

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[1] Renauld & Cardot: *Bot. Gaz.*, xiv (1889), 99.
[2] *Homalothecium Nevadense* Ren. & Card.: *Bot. Gaz.*, xiii (1888), 202.
[3] Kindberg: *Bull. Torr. Bot. Club*, xvi (1889), 97.
[4] Renauld and Cardot: *Bot. Gaz.*, xiii (1888), 202, pl. XX.

ii. *Leaves not deeply plicate.*

[**Homalothecium pseudo-sericeum** may be sought here.]

* *Lid convex-conic to long-conic (rostellate in* 59).

+ *Leaf-cells not abruptly enlarged at base, upper usually distinct, elongated rhombic.*

++ *Seta smooth above, rough below, capsule suberect.*

- Capsule 1:1.5, cilia 2, equalling teeth . . . **H. Hillebrandi, 46.**
- Capsule 1:2.5, cilia solitary, short, or none . . **H. Fendleri, 47.**

++ ++ *Seta smooth below, rough above, capsule cernuous or arcuate.*

- Perichætial leaves short-acuminate . . . . **H. plumosum, 58.**
- Perichætial leaves abruptly long filiform-acuminate **H. campestre, 54.**

++ ++ ++ *Seta rough throughout.*

= *Cells of basal angles scarcely different.*

- Leaves scarcely or abruptly acuminate, dioicous.
  - Leaves very short acuminate, glossy, not decurrent **H. rivulare, 56.**
  - Leaves short acuminate, broadly and long decurrent, **H. latifolium, Lindb.**[1]
  - Leaves longer acuminate, not glossy, decurrent . **H. Novæ-Angliæ, 55.**
- Leaves gradually acuminate, autoicous.
  - Slender, leaves lanceolate to ovate-lanceolate, capsule constricted under mouth when dry . . **H. velutinum, 45.**
  - Stout, leaves ovate, capsule not constricted . **H. rutabulum, 52.**

= = *Cells of basal angles distinctly quadratic.*

- Leaves long acuminate, costa entering point . . **H. reflexum, 50.**
- Leaves acuminate, costa not reaching point.
  - Seta long (4 cm. +) . . . . **H. asperrimum, 53.**
  - Seta shorter (2 cm. —).
    - Segments split between articulations . . **H. œdipodium, 51.**
    - Segments split their whole length[2]
      - Seta arcuate above . . . . **H. Bolanderi, 48.**
      - Seta abruptly bent at base of capsule . . **H. Starkii, 49.**

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[1] Renauld and Cardot: *Fl. Miq.* (1888) 51.

[2] According to Austin *Bot. Gaz.*, iv (1879), 162, the pedicel of *H. biventrosum* (40) is obsoletely scabrous, and it might therefore be sought here.

+ + *Leaf-cells abruptly enlarged at base, indistinct, linear-vermicular.*

Costa percurrent . . . . **H. populeum, 57.**
Costa vanishing.
  Seta purplish, rough throughout.
    Capsule suberect, stem-leaves gradually acuminate **H. cæspitosum, 59.**
    Capsule abruptly horizontal, leaves abruptly short acuminate with points recurved . . **H. illecebrum, 61.**
  Seta reddish and rough above, yellowish and smooth below . . . . **H. Californicum, 60.**

* * *Lid (more or less long) rostrate.*

+ *Leaves obtuse* . . . . **H. obtusifolium, 169.**

+ + *Leaves acute or acuminate.*

++ *Cilia solitary or geminate at base.*

Perichætial leaves erect, serrulate . . . . . **H. curvisetum, 91.**
Perichætial leaves recurved, entire . . . . . **H. lentum, 69.**

++ ++ *Cilia 2—3.*

Leaves with filiform points.
  Stems short, with erect fasciculate branches, stoloniferous . . . . **H. Vaucheri, 73 a.**
  Stems long, prostrate, irregularly branched, not radiculose . . . . **H. piliferum, 74.**
Leaf-points not filiform.
  Leaves serrulate all around.
    Decurrent, excavate at basal angles.
      Perichætial leaves spreading . . . . . **H. Stokesii, 78.**
      Perichætial leaves reflexed . . . . . **H. Oreganum, 79.**
    Not decurrent nor excavate.
      Leaves ovate-lanceolate, acuminate, segments split . . . . **H. Sullivantii, 76.**
      Leaves broad-ovate, acute, segments perforate **H. prælongum, 75.**
  Leaves entire at base.
    Lid not half as long as capsule . . . **H. colpophyllum, 73.**
    Lid nearly as long as capsule . . . . . . **H. hians, 77**

b. *Seta smooth.*

[**Homalothecium pseudo-sericeum** may be sought here.]

i. *Lid (more or less long) rostrate.*

Leaves apparently 2-ranked; plants of dry woods . **H. serrulatum, 89.**

Leaves spreading every way.
Ovate, acute, rarely slender-pointed; in water . **H. rusciforme**, 90.
Deltoid, with long slender points.
Points twisted, plants golden yellow . . . **H. Boscii**, 72.
Points straight.
Spreading, branchlets attenuate . . . **H. strigosum**, 70.
Appressed, branchlets short, julaceous . **H. diversifolium**, 71.

ii. *Lid convex to conic.*

* *Leaves acute or acuminate, serrulate.*

+ *Primary branches erect, dendroid to fasciculate, capsule symmetric, suberect or inclined.*

++ *Leaves papillose on back.*

In compact tufts, dark green, branchlets not attenuate **H. Brewerianum**, 66.
In loose tufts, branchlets attenuate, stoloniferous.
Cilia solitary, margin of stem leaves reflexed . **H. spiculiferum**, 64.
Cilia 2—3, margin of stem leaves not reflexed . **H. stoloniferum**, 63.

++ ++ *Leaves smooth.*

Capsule cylindrical, cilia solitary, ½ segments . **H. aggregatum**, 67.
Capsule oval-oblong, cilia 2—3.
Perichætial leaves serrate . . . . . **H. myosuroides**, 62.
Perichætial leaves entire . . . . **H. acuticuspis**, 65.

+ + *Primary branching irregular or pinnate, capsule unsymmetric, subarcuate, horizontal* (excl. 36 and 44).

Capsule symmetric, erect.
Synoicous, small (branches 1 cm. long) . . . **H. Utahense**, 44.
Dioicous, large (branches 3—4 cm.) . . . . **H. acuminatum**, 36.
Capsule unsymmetric, inclined.
In loose tufts, plants stout or long.
Leaves narrowed from lower third to apex, usually whitish or yellowish.
Capsule short (1:1.5), monoicous, leaves straight when dry . . . . **H. salebrosum**, 37.
Capsule short (1:1.5—2), dioicous, leaves twisted-flexuous when dry . . . . **H. Thedenii**, 41.
Capsule longer (1:3), dioicous, leaves straight when dry . . . . **H. lætum**, 35.
Leaves narrowed from base to apex, bright green, monoicous . . . . **H. acutum**, 38.

In loose tufts, plants small, bright green, dioicous **H. biventrosum**, 40[1].
In dense hemispherical bright green tufts, monoicous **H. collinum**, 43.

* * *Leaves acute or acuminate, entire.*

+ *Capsule strongly constricted under mouth when dry.*

Leaves widest just at base, tapering equally.
  Deeply plicate, cells obscure . . . . **H. nitens**, 33.
  Concave, smooth, cells plain . . . . . **H. polygamum**, 132.
Leaves widest above base, long-acuminate . **H. chrysophyllum**, 130.
Leaves widest above base, not acuminate . . . **H. palustre**, 165.

+ + *Capsule slightly or not constricted.*

Plants reddish-brown below, orange above . . . **H. badium**, 183.
Plants whitish-, yellowish- or bright green.
  Cilia 0, basal cells quadrate, numerous . . . **H. Donnellii**, 42.
  Cilia 2.
    Monoicous, leaves open . . . . . . **H. salebrosum**, 37.
    Dioicous, leaves appressed-imbricate . . . **H. albicans**, 39.
  Cilia solitary.
    Alar cells loosely quadrate, thin . . . **H. oxycladon**, 53a.
    Alar cells round-quadrate, obscure. . . . **H. apocladum**, 68.

* * * *Leaves obtuse (sometimes apiculate in* 175) *entire.*

+ *Cells not enlarged at basal angles.*

Leaves open . . . . **H. arcticum**, 168.
Leaves closely imbricate . . . . **H. trifarium**, 181.

+ + *Cells enlarged at basal angles.*

Costa subpercurrent.
  Monoicous, sparingly branched, alar cells gradually enlarged . . . . **H. cordifolium**, 173.
  Dioicous, profusely branched.
    5—10 cm. long, variegated or dark purple, stolons green . . . . **H. sarmentosum**, 175.
    15—30 cm. long, bright- to yellowish green . **H. giganteum**, 174.
Costa reaching middle.
  Branches irregularly pinnate, leaves spreading . **H. Richardsoni**, 177.
  Branches few, leaves imbricate . . . . **H. stramineum**, 180.

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[1] The sterile *H.* (Brachythecium) *Fitzgeraldi*, Müller (*Flora*, 1887, 224), is related to this species and distinguished from it "by its parallel julaceous-terete branches and larger, broader and less acuminate leaves."

2. *Costa very short or none or double.*

a. *Alar cells abruptly enlarged (often inflated and colored).*[1]

i. *Operculum long subulate rostrate.*

- Capsule horizontal, strongly constricted under mouth when dry, leaves quite entire . . . . . . **H. demissum**, 80.
- Capsule suberect, slightly constricted, leaves serrulate at apex . . . . **H. microcarpum**, 84.
- Capsule inclined, wide mouthed, leaves spinulose-dentate at apex . . . . **H. laxepatulum**, 86.

ii. *Operculum short rostrate.*

- Leaves roundish elliptical, subacute or apiculate . **H. Novæ-Cesariæ**, 81.
- Leaves filiform acuminate.
  - Cilia 2, annulus 0, capsule oblong (1:2—2.5) . . **H. recurvans**, 82.
  - Cilia 0, annulus 0, capsule cylindric (1:3.5) . . **H. cylindricarpum**, 83.
  - Cilia 1, annulus simple, large, capsule oblong . . **H. Jamesii**, 85.
- Leaves acute or stoutly acuminate.
  - Entire . . . . **H. Haldanianum**, 163.
  - Sharply serrate . . . . **H. nemorosum**, 164.

iii. *Operculum convex or conic.*

- Leaves falcate.

  [**H. palustre, var. hamulosum** may be sought here.]

  - Scarcely costate, alar cells orange . . . . . **H. eugyrium**, 171.
  - Costa reaching middle, alar cells hyaline . . **H. ochraceum**, 172.
- Leaves not falcate.
  - Abruptly filiform apiculate, entire, alar cells not conspicuous . . . . **H. trichophorum**, 100.
  - Gradually filiform acuminate, alar cells orange.
    - Acute or short apiculate, alar cells few, large . **H. palustre**, 165.
      - Plants slender, 2—3 cm. long.
        - Branches erect, leaves serrate . . **H. Muhlenbeckii**, 111.
        - Branches intricate, leaves nearly entire . **H. Fitzgeraldi**, 112.
      - Plants stout, 7—10 cm. long, leaves quite entire **H. stellatum**, 131.
    - Obtuse, entire, alar cells hyaline . . . **H. cuspidatum**, 176.

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[1] In 81 so few as to be easily overlooked.

b. *Alar cells scarcely different or quadrate, not abruptly enlarged.*

1. *Leaves thin, glossy, open; plants mostly small, prostrate or with ascending branches.*

* *Leaves complanate.*

+ *Lid rostrate.*

Leaves transversely undulate, serrulate at apex	**H. undulatum**, 110.
Leaves not undulate, quite entire	**H. sylvaticum**, 109.
Leaves not undulate, serrulate to base.	
Bicostate, annulus large	**H. geophilum**, 87.
Uni- or ecostate, annulus 0	**H. deplanatum**, 88.

+ + *Lid convex or conic.*

Capsule pendent	**H. elegans**, 105.
Capsule suberect, inclined or horizontal.	
Sulcate and constricted below mouth when dry	**H. turfaceum**, 104.
Smooth when dry.	
Autoicous, plants growing on rotten wood.	
Annulus 0	**H. micans**, 103.
Annulus large, triple	**H. denticulatum**, 106.
Dioicous, plants growing on stones or the ground.	
Leaves quite entire, capsule obovate, campanulate when dry	**H Muellerianum**, 107.
Leaves serrulate, capsule subcylindric	**H. Sullivantiæ**, 108.

* * *Leaves equally spreading.*

+ *Capsule suberect, smooth when dry.*

Dioicous, cilia 0, costa obsolete.	
Inner perichætial leaves ovate lanceolate	**H. latebricola**, 98.
Inner perichætial abruptly acuminate	**H. Passaicense**, 99.
Autoicous, cilia 2—3, costa double.	
Thick, ascending to middle	**H. geminum**, 102.
Thin, reaching half way to middle	**H. denticulatum**, var. 106.

+ + *Capsule inclined, sulcate when dry*	**H. pseudo-Silesiacum**, 113.

+ + + *Capsule inclined or horizontal, often arcuate, smooth when dry.*

Leaves squarrose, abruptly long acuminate	**H. hispidulum**, 129.
Leaves loosely imbricate, obtuse or acute, alar cells orange.	
Nearly as broad as long, obtuse or apiculate	**H. molle**, 166.
Nearly twice as long as broad, acute, point often half twisted	**H. alpestre**, 167.
Leaves falcate, gradually acute	**H. montanum**, 170.

ii. *Leaves firm, plants very large, mostly* 1—2-*pinnate, erect or ascending.*

* *Paraphyllia 0.*

Leaves obtuse or abruptly apiculate.
Capsule smooth when dry.
Leaves obtuse.
Olive or grayish green, 1—2-pinnate, leaves open **H. Schreberi,** 178.
Dirty green to dark brown, almost simple, leaves closely appressed . . . . **H. trifarium,** 181.
Leaves abruptly apiculate, plants pale green . **H. purum,** L.[1].
Capsule plicate when dry, plants dark green to reddish brown . . . . **H. scorpioides,** 184.
Capsule unknown; plants dark yellow and greenish, branches julaceous, few, fastigiate, leaves short apiculate **H. turgescens,** 182.
Leaves long acuminate.
Sulcate.
Apex blunt . . . . **H. Flemmingii,** 191.
Apex very sharp.
Ecostate, leaf cells all alike . . . . . **H. loreum,** 192.
Bicostate, leaf cells enlarged at base . . **H. triquetrum,** 190.
Not sulcate . . . . **H. squarrosum,** 189.

* * *Paraphyllia present.*

Leaves with long double costa, leaves deeply sulcate **H. umbratum,** 186.
Leaves obscurely bicostate.
Obtuse . . . . **H. Alaskanum,** 179.
Acute or apiculate or long acuminate.
Paraphyllia pinnate, branches densely 2—3 pinnate **H. splendens,** 185.
Paraphyllia minute, branching irregularly pinnate **H. brevirostre,** 188.
Leaves unicostate to middle, coarsely serrate . . **H. Oakesii,** 187.

II. *Leaves secund.*

[**Raphidostegium** spp. and **Brachythecium Thedenii** may be sought here.]

A. *Costa single, reaching to the middle or beyond.*

1. *Cells short, minute* . . . . **H. crispifolium,** 22.

2. *Cells elongated.*

a. *Seta rough.*

Leaves serrulate . . . . **H. velutinum,** 45.
Leaves entire . . . . **H. plumosum,** var. 58.

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[1] Renauld and Cardot: *Fl. Miq.* 57.

b. *Seta smooth.*

i. *Leaves transversely rugose and longitudinally plicate.*

Plants slender . . . . **H. aduncum var. gracilescens,** 133.
Plants very stout.
Leaves serrate at apex, alar cells quadrate . . **H. rugosum,** 144.
Leaves subserrate at apex, alar cells scarcely different, **H. robustum,** 145.

ii. *Leaves not rugose, often plicate.*

* *Alar cells much enlarged or differently colored.*

+ *Paraphyllia abundant (rarely few).*

Leaves plicate . . . . **H. commutatum,** 143.
Leaves not plicate . . . . **H. filicinum,** 142.

+ + *Paraphyllia 0.*

Annulus 0.
Autoicous, leaves quite entire . . . . . . **H. palustre,** 165.
Autoicous, leaves denticulate . . . . . . **H. fluitans,** 136.
Dioicous, leaves entire above, serrulate below **H. exannulatum,** 137.
Annulus large.
Autoicous, leaves plicate, teeth orange at base, yellowish above . . . . **H. uncinatum,**[1] 135.
Dioicous, leaves sulcate, teeth orange with a broad hyaline border . . . . **H. ochraceum,** 172.
Dioicous, leaves striate, teeth brown or dark orange, not bordered.
Alar cells pellucid . . . . **H. aduncum,** 133.
Alar cells orange . . . . **H. Sendtneri,** 134.

* * *Alar cells small or scarcely different.*

Leaves serrate . . . . **H. Thedenii,** 41.
Leaves quite entire.
Plants very large and stout (15—20 cm.), leaves costate to near apex.
Regularly pinnate . . . **H. aduncum var. hamatum,** 133.
Irregularly and dichotomously branched . **H. lycopodioides,** 140.
Plants much smaller, leaves obscurely bicostate . . **H. Watsoni,** 141.
Plants much smaller, leaves costate to above middle.
Autoicous, purplish-red, red-brown or nearly black **H. revolvens,** 138.
Dioicous, dirty green or yellow . . . **H. vernicosum,** 139.

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[1] *Hyp. symmetricum* Ren. et Card. (*Bot. Gaz.* xiv (1889), 99, pl. xv), is a sub-species of H. uncinatum, from which it is distinguished by the "narrower, erect and quite symmetric capsules, sometimes clustered by two in same perichætium."

B. *Costa double, short, or none.*

1. *Alar cells enlarged, hyaline or colored.*

a. *Lid conic, often apiculate, capsule oval to oblong* (1:1—2.5).

i. *Alar cells pellucid, not conspicuously colored.*

* *Capsule costate and arcuate when dry.*

Alar cells short, yellow, thick walled . . . **H. curvifolium,** 159.
Alar cells inflated, hyaline, thin-walled . . **H. arcuatum,**[1] Lindb.

* * *Capsule not costate when dry.*

Vaginule short (1: 2) covered with longer hairs . **H. molluscum,** 147.
Vaginule longer (1:3+)
  Plants shining yellow, leaves subserrulate . **H. depressulum,** 151.
  Plants bright- to pale green, leaves quite entire.
    Lid sharply apiculate, orange, capsule incurved when dry . . . . **H. callichroum,** 154
    Lid not apiculate, capsule strongly arcuate when dry **H. pratense,** 161.

ii. *Alar cells orange.*

Leaves quite entire . . . . **H. Bambergeri,** 162.
Leaves serrulate.
  Ecostate . . . . **H. circinale,** 152.
  Obsoletely bicostate . . . . **H. Sequoieti,** 153.

b. *Lid rostrate, capsule cylindric* (1: 3.5 +).

Leaves laterally compressed both sides, alar cells orange **H. Bambergeri,** 162.
Leaves not laterally compressed.
  Perichætial leaves bicostate to middle, plicate . . **H. reptile,** 148.
  Perichætial leaves shortly bicostate, plicate . **H. cupressiforme,** 158.
  Perichætial leaves ecostate, plicate, cilia solitary, appendiculate . . . . **H. imponens,** 155.
  Perichætial leaves ecostate, not plicate, cilia 2, inappendiculate . . . . **H. subimponens,** 156.

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[1] Renauld and Cardot: *Fl. Miq.* 55.

2. *Alar cells not distinct, often quadrate.*

a. *Plants very stout* (5—6 *mm. thick*), *leaves transversely rugose* . . . . **H. robustum**, 145.

b. *Plants much more slender* (2 *mm. or less thick*), *leaves not rugose.*

Costæ 2, thick, reaching the middle . . . . . **H. geminum**, 102.
Ecostate or shortly bicostate.
  Irregularly branched.
    Leaf margins reflexed, shortly bicostate . . **H. plicatile**, 157.
    Leaf margins plane, shortly bicostate . . **H. Vaucheri**, Lesq.[1]
    Leaf margins plane, ecostate . . . . . **H. pulchellum**, 101.
  Regularly pinnate.
    Plants very large (to 15 cm.), capsule arcuate, stem leaves plicate . . . . **H. Crista-castrensis**, 146.
    Plants smaller (usually less than 5 cm.), capsule not arcuate nor stem leaves plicate.
      Perichætial leaves plicate.
        Leaves quite entire . . . . **H. complexum**, 160.
        Leaves serrulate at apex.
          Inner perichætial leaves costate . . . **H. fertile**, 149.
          Inner perichætial leaves ecostate . . **H. hamulosum**, 150.
      Perichætial leaves not plicate . . . **H. subimponens**, 156.

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[1] Renauld & Cardot: *Bot. Gaz.* xiv. (1889) 100.

SOME ADDITIONAL EVIDENCES BEARING ON THE INTERVAL BETWEEN THE GLACIAL EPOCHS.

BY PRESIDENT T. C. CHAMBERLIN.*

Evidences bearing upon the interval between the glacial epochs may be drawn from various parts of the glaciated field and from the various phenomena connected with glaciation. It is not, however, my purpose to make any approach to an exhaustive review of these evidences, or even to touch upon the arguments that may be drawn from all the several sources. I desire simply to bring to your attention certain specific evidences that have an important bearing upon the length of the main interglacial interval and that lend themselves more readily to intellectual estimation than others. The evidences that are especially additional to previous knowledge are drawn from the lower Mississippi Valley, but, in connection with these, I shall briefly refer to evidences drawn from other valleys that fall into marked harmony with these.

In the lower Mississippi Valley, the sub-stratum consists of Tertiary deposits. Upon these there is a thin stratum of gravel and sand, known heretofore quite widely as the Orange Sands, although that term seems to have been applied to different formations. This stratum has been very considerably misunderstood. It does not contain, so far as critical investigation shows, any material that may be regarded as glacial, although I think in some of the earlier reports Archean pebbles were cited as an indication that these gravels were contemporaneous with the glacial deposits of the north. They have been critically examined during the summer by my colleague, Professor Salisbury, and during the entire season's search he has not found a single pebble that is referable to a glacial origin. Some years since I examined the same formation with like result. Professor Call has also examined some of these deposits with a similar result. The pebbles are chiefly of chert and were derived from the chert-bearing limestones, largely Carboniferous, but reaching as far down as the Lower Magnesian limestone. They are, therefore, non-glacial. This is a matter of some importance as these sands and gravels have been correlated with the glacial deposits not only but referred to the Champlain epoch. They are very far removed from the Champlain deposits in time. That correlation is one of the great errors of Quaternary geology. They are certainly pre-

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* The facts relative to the Lower Mississippi region are drawn largely from the observations of my associate, Prof. R. D. Salisbury.

glacial in the sense that they were not contemporaneous with the glacial incursion at its earliest maximum. They may have been contemporaneous with the very earliest stages of glaciation before the ice reached the Mississippi Valley and was able to mingle its deposits with those of valley.

Now these gravels occupy a wide area stretching across the basin of the lower Mississippi from some distance back in Tennessee, Kentucky and Mississippi to the high lands upon the Arkansas side, appearing in Crowley's ridge that bisects the present bottoms of the Mississippi. The gravel stratum undoubtedly was originally horizontal, but it now undulates more or less conformably with the surface. The explanation of this, it seems to me, is found in the gradual creep of the soft material of the hills as they were slowly carved out by erosion. The brows of the hills in some cases have obviously crept down on the slopes, for on the summit we find the gravels compact and firm and the constituent pebbles lying with their maximum diameters in a horizontal position while the stratum has level upper and lower bounding planes. On the slopes of the hills however the gravel beds are more or less broken up, and the pebbles have been disturbed and displaced and tumbled into various attitudes, such as we might naturally expect under the hypotheses of a creeping movement on the slope. It seems impossible to suppose that this stratum of gravel was originally deposited in the undulatory form in which it is now found. It might be supposed that the silt which overlies this gravel bed was deposited as a mantle over an undulatory surface, but gravel does not lend itself to such a method of distribution.

This overlying mantle, which now claims attention, consists of fine silt and embraces the loess deposits of the lower Mississippi. It spreads out broadly over the gravel stratum and extends somewhat beyond it, especially on the east. This stratum is in places differentiated into two parts and separated by a soil-like horizon. This differentiation is not common to the entire valley. This silt mantle may be traced almost in unbroken continuity northward to the border of the glacial drift, whence it spreads itself over the drift, reaching up on it some hundreds of miles to the northward. In this northern stretch the silt mantle is correlated with a second episode of the earlier glacial epoch. It graduates down into a stratum of boulder clay that overlies a bed of vegetable material, which in turn overlies another till. Both of these tills I have been accustomed to correlate with the earlier glacial epoch. I do not wish, however, to raise differences of opinion on that point here. It is unimportant to the main conclusions which we desire to reach.

Besides this continuity there is a further reason for regarding these silt deposits as contemporaneous with the ice invasions. They are made up in part of glacial particles; that is, particles derived from the mechanical abrasion of a glacier. These particles consist of decomposable silicates, dolomites and limestones, and were rasped from rocks of these varieties lying further north. Such decomposable particles do not abound in residuary clays but are abundant constituents of glacial clays.

It seems necessary to suppose that this mantle of loess and loess-like silt was originally deposited as a horizontal stratum across the entire Mississippi bottoms. At the present time it undulates over the hills. At first thought it would seem that the depositing waters might have been deep and the silt laid down as an undulatory mantle; but it would seem necessary to extend the same hypothesis to the deposition of the gravels where its application is manifestly excluded by the nature of the deposit. I feel sure from observation in certain cases that full investigation will show that this seeming mantling is the result of the gradual degradation of the hills, accompanied by creep of the pliant and plastic material. This phenomenon of creep has a wide expression entirely independent of the area uncer consideration; but upon that I cannot dwell.

During the first glacial episode the altitude and slope of the lower Mississippi basin was so low as to permit the deposit of this silt on the bluffs which are now 200 feet more or less above the present Mississippi bottoms. Before the second glacial epoch, according to the division I make, there was an elevation sufficient to permit the erosion of the great trench of the lower Mississippi by the predecessor of the present river. This erosion amounts in round numbers to a trench about 300 feet in depth and about sixty miles in width. Some of the bluffs that are crowned by these silts are 200 or 250 feet in height, and Professor Call's recent investigations show 80 to 100 feet of silt in the bottom. It is, therefore, I think, safe to say that in round numbers there was an erosion during the interval between the two epochs of the magnitude named and reaching from Cairo south to the gulf with corresponding erosion trenches along the upper branches. This great erosion represents the interval between the formation of the silts of the earlier glacial epoch and the filling in of the valley deposits of the later glacial epoch, which now demand our attention. If we go back on the glaciated area to the moraines which mark the limit of the later glacial incursions, we shall find, starting from the outer side of these moraines, valley streams of gravel formed contemporaneously with these ice incursions. Tracing these gravel streams along their courses, we find that they run down into the channels cut in the inter-glacial interval, and partially fill them. On the upper Mississippi, on the Chippewa, on the Wisconsin and on other tributary rivers, we find gravel trains heading on the outer edge of the outer moraine of the later epoch. Passing down through the interglacial trenches, these are found represented in the lower Mississippi valley, as I think we may safely say from recently gathered evidence, as deposits in the Mississippi bottoms, overlaid of course by the more recent deposits. The work of the earlier glacial epoch in the lower Mississippi I conceive to be the deposit of the loess and loess-like silt, that of the interglacial epoch to be the erosion of the great trench in which the Mississippi bottoms now lie, and that of the later glacial epoch to be the partially filling of this trench. The trenching is the measure of the interglacial interval, or at least is a partial measure of it.

If we pass to the upper Ohio and Allegheny valleys we find phenomena that fall into close correspondence with the foregoing. There are high shoulders and terraces at various points which bear upon themselves glacial river gravels. One of the most decisive is found in the vicinity of Parkers, and has been described by Mr. Chance and others. Here an old channel runs back from the present course, and curving around a group of hills, returns, forming an "ox bow." In this old channel glacial river gravels are found, showing that it was occupied contemporaneously with some stage of the glacial period. This abandoned channel is about 200 feet above the present Alleghany river. Mr. Chance tells us there is about fifty feet of drift in the present valley bottom. So between this upper river bed and the bottom of the present rock channel there is evidence of an erosion of 250 feet, 200 of which, in round numbers, are cut through Carboniferous strata. Similar and corroborative facts show themselves along the course of the river above and below and along the Monongohela and the upper Ohio. If we trace the old channel of the Alleghany northward by means of remnant shoulders and terraces we find that it lies considerably above the altitude of the terminal moraines of the later epoch; and also much above the gravel trains that head on the outer side of these moraines and run down through the trench above indicated. It therefore becomes a necessary inference that the trench was cut before the moraines were pushed across it and before the moraine derived gravels could be carried down into it. The trench therefore represents the interval between the earlier and the later glacial epochs. I have placed in manuscript elsewhere the fuller facts upon which these brief statements rest, and they will appear in print in time.

If we pass over the Susquehanna valley we find like phenomena. These have been brought out by Mr. McGee and others and I need only to refer to them because of their connection with that which I have already presented. Here we find old benches covered with rounded pebbles — some of which are glaciated — reaching to a similar height of about 250 feet above the present Susquehanna river. There are glaciated pebbles at higher altitudes, but I have taken the more moderate figure because it is a safe one. Near Sunburg glaciated stones were found by Professor Salisbury about six hundred feet above the present river. Below these high terraces and in the valley excavated out of the plain from which they were derived, we find a lower terrace 60 or 70 feet in height of newer and distinguished aspect. Above Berwick this lower terrace connects itself definitely with the terminal moraine which there crosses the river. The terrace rises rapidly as it joins this moraine, as is the habit of moraine-headed terraces, and reaches an altitude of 100 to 150 feet as it merges into the moraine. But it is still much below the old terraces from which it is sharply distinguished by its freshness and youth and by its constituent material.

It appears therefore that at this point a deep trench was cut in the flood-plain of which the old terraces are the remnants before the formation of the later moraine and of the valley deposits that sprang from it.

If we pass over to the Delaware valley we find analagous facts which are more familiar through the writings of several geologists. Many years ago Professor Lewis called attention to the earlier and later deposits of that region, though he did not give them the interpretation I shall place upon them here, which coincides essentially with that of McGee. As we follow up the valley toward Belvidere where the moraine crosses the Delaware, we find old terraces reaching up to about 240 or 250 feet upon which are rounded pebbles and glaciated stones, indicating an origin in the earlier stage of glaciation. Cutting through these old plains and the rock below we find the deep trench in which the later deposits have been placed. These later gravel deposits, originating with the moraine at a height of somewhat above 150 feet, rapidly decline to about 85 feet a few miles above Lewisburg, opposite a point where the older terrace rises to about 250 feet. The measure of the interval here is some 250 to 300 feet of rock cutting.

It would appear therefore that while there are local variations, there is a general correspondence between the amount of erosive work done by the lower Mississippi, by the upper Ohio and Alleghaney, by the Susquehanna and by the Delaware rivers respectively. The facts indicate that the altitude of the continent was low in the closing stages of the earlier glacial epoch; became higher in the interglacial interval, and after sufficient time elapsed for these great erosions to take place, the glacial waters of the later epoch poured their valley deposits down the trenches formed in the interval. The cutting of these trenches rudely measures the length of this interval or at least the length of the actively erosive part of it.

ON THE APPENDAGES OF THE FIRST ABDOMINAL SEGMENT OF EMBRYO INSECTS.

By WM. M. WHEELER.

Much of what is contained in the following paper was presented to the Wisconsin Academy of Sciences, Arts and Letters at its annual meeting in December, 1888. *Graber's* summary ['88], embodying as it does all that was known of the curious organs on the basal abdominal segment of embryo insects up to 1888, would seem to render superfluous a second general contribution at so early a date. Nevertheless I have been led to undertake the task for several reasons: First, several brief articles have appeared since the publication of *Graber's* comprehensive paper; secondly, I have myself made some observations which fill a few of the gaps necessarily left in the German investigator's resumè, and thirdly, as I take a very different standpoint in regard to the interpretation of the problematic appendages, I feel in duty bound to reproduce all the facts from which my conclusions are drawn.

This paper does not purport to be a final monograph on the subject—such a task can be undertaken only when the embryos of many more insects have been carefully studied—but a resumè of facts and theories up to the close of 1889. After giving an account of my own investigations in the first part, I shall in the second portion pass to an account of the work of other observers, and in the last part consider the theories which have been advanced in regard to the original function of the problematic organs. The descriptions of the organs in *Blatta* and *Periplaneta* and the whole of the theoretical portion are essentially the same as when presented to the Academy in December, 1888.

For the sake of avoiding repeated circumlocution I shall call the appendages of the first abdominal segment *pleuropodia*—a name both suggestive of their origin from foot-like organs and their tendency, when fully developed, to take up a position on the pleural wall of the embryo. Should the theory advanced in the latter part of the paper prove to be correct, I would suggest that the term *adenopodium* be substituted for *pleuropodium*.

I shall not treat of the abortive and very transient appendages which appear on some or all of the abdominal segments, since the interested reader will find a complete resumè of our fragmentary knowledge of these structures in *Graber's* paper ['88]. Nor do I propose to enter into the controversy as to whether the ancestral insects were homopod or heteropod, because I believe, in contradiction to *Graber*, that there is nothing in the structure or evolution of the pleuropodia which throws any light whatever on the mooted question.

These organs may be turned to quite as good account by the advocates of homopody as by those who accept *Graber's* views. Supposing the Diptera were the only order of insects of which we had any knowledge, should we be justified in asserting that the halteres which now function as sense organs according to *Leuckart* and *Lee*, had never functioned as true wings? Certainly not. No entomologist doubts that the immediate ancestors of the Diptera were true insects and that they were provided with two pairs of perfect wings. It seems to me that the advocates of homopody may logically maintain that the pleuropodia present a strictly analogous case. These organs originate as appendages homologous with the thoracic legs though they subsequently differentiate into organs of problematic though certainly not ambulatory function. Why might not the pleuropodia have been true ambulatory appendages in ancestral forms no more remote from the living or even Palæozoic Orthoptera than some four-winged insects are from the Diptera?*

PART FIRST.

Blatta (*Phyllodromia*) *germanica.* L.

(Plate I, Figs. 1-9.)

The appendages of the embryo Blatta begin to appear on the tenth day from the formation of the polar globules. The antennae and the three pairs of thoracic limbs are the first to rise from the ectoderm of the hammer-shaped embryo. By the eleventh day the three pairs of oral and several

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*A similar argument may be advanced in the case of the hamulate halteres of the male *Coccidæ*. Of deeper interest in this connection, however, are two facts recorded by Schioedte (De Metamorphosi Eleutheratorum Observationes, Kopenhagen, 1861-1883) concerning larval *Scarabæidæ* and *Lucanidæ*. In the larvæ of most species belonging to these families the metathoracic legs are as long as or a little longer than the meso- and prothoracic pairs. The larval *Geotrypes stercorarius*, L., however, has the hind legs reduced to only half the length of the anterior pairs. (Plate XVI, Fig. 1.) In the larval *Passalus cornutus*, Fabr. the hind legs are so far reduced as to be represented by a pair of small rudiments only. "Pedes tertii paris valde deminuti *Geotrypæ*, *Passalo*, completi *Geotrypæ*, femoribus, tibiis, unguliს carentes *Passalo*." It is interesting to note that the rudiments in *Passalus*, as shown in Schioedtes' Figure (Plate XVIII, Fig. 12) are placed very near and somewhat pleurad to the bases of the median legs. The position thus assumed by the atrophied hind legs in respect of the median pair is exactly the same as that assumed in insect embryos by the pleuropodia in respect of the hind or metathoracic pair. The possibly unique, and certainly anomalous reduction of the hind legs in the larval *Geotrypes* and *Passalus* is well suited to show what striking changes may occur in the appendages within the limits of a single suborder of insects. This reduction, which is a purely larval character, since the imagines have hind legs of the usual size and structure, has very probably taken place within comparatively recent times.

pairs of rudimentary appendages on the abdominal segments have become visible. All the appendages are merely glove- finger-shaped outgrowths of the ectoderm into each of which extends a similar evagination of the underlying mesodermic somite. [Fig. 2.] Of the abdominal appendages all except the first pair soon disappear entirely. They are nipple-shaped elevations which are brought down to the general surface of the abdominal ectoderm by the tension resulting from the lateral and longitudinal growth of the embryo. The first pair of abdominal appendages in embryos twelve days old [Fig. 2 ap.], is twice as long as any of the succeeding evanescent appendages, and about half as long as the metathoracic legs.

Had I figured the whole of the sagittal section, of which Fig. 2 represents only a small portion, it would be seen that the three pairs of thoracic appendages are of equal length, and together with the antennae, the longest and most prominent appendages of the embryo. The abdominal pair is longer than the mandibles in this stage, but only about two-thirds as long as either the first or second maxillæ. Like the antennæ, oral and ambulatory appendages, they are directed obliquely outward and backward. The evanescent abdominal appendages, on the other hand, are directed forward.

The further differentiation of the antennæ, mandibles, maxillæ and feet is brought about by a very rapid proliferation of the constituent ectodermic cells, by a somewhat less rapid proliferation of the cells of the mesodermic somites of the appendages to form muscles, and by constrictions of the surface to form the joints of the adult insect. The differentiation of the first abdominal appendage is brought about in quite a different manner, namely, by the modification of the individual ectodermic cells of which its outer layer consists.

The appendage ceases to grow much in length after the twefth day and its cells no longer divide. I have never seen a nucleus in any phase of either karyokinesis or karyostenosis, notwithstanding I have examined many sections in all stages of development. Hence the number of cells which constitute the appendage on the twelfth day remains constant till the organ disappears. The cells which form all but its basal portion increase enormously in size, assuming the shape of long prisms more or less attenuated in some portion of their length. They grow inward and push the mesodermic cells which at first grew forward into the appendage, back into the body of the embryo. The cyptoplasm of these large cells consists of finely and evenly granular protoplasm in which there are one or two spherical or oval vacuoles at the peripheral ends. [Fig. 3, 4, *v.*] In surface views the cells are polygonal. The contour of the inner ends is indistinct in embryos fourteen days old.

Not only does the cytoplasm of each of the formerly small ectodermic cells increase thus enormously, but also the nuclei, which assume a centrifugal position in the fanshaped sections of the appendage. Owing to their number the nuclei are forced to arrange themselves in several rows.

[Fig. 3.] The karyochylema of these nuclei is colorless and shows no granulation. Through it are spread what under a low power appear to be distinct but isolated masses of chromatin.

Under a power of about 900 diameters the prismatic cells exhibit more of their true structure. The protoplasmic reticulum of the cytoplasm is indistinctly seen, most of its exceedingly delicate threads running parallel with the long diameter of the cells and presenting the appearance of fine striation. The parallel arrangement in this direction may be due to the tension of the protoplasm during the rapid centripetal growth of the cells. The nodes of the cytoplasmic reticulum are what appear as fine granules under a low power. The vacuoles are colorless and are probably only drop-like accumulations of cytochylema. In the nucleus the karyochylema is perfectly colorless and through it runs a net-work of chromatin which appears to have thickened nodes. A nucleolus, which stains but very slightly, usually occupies a central position. By focussing the distribution of the chromatic reticulum is distinctly seen to be peripheral and not suspended in the karyochylema. When only the equatorial plane of the nucleus is in focus the thick masses of chromatin are seen to be closely applied to the wall of the nucleus — only a few of them running out into the limpid karyochylema. The thin strands of chromatin connecting the irregular masses probably also run along the inner face of the nuculear wall. Fig. 5 represents five nuclei drawn with the focus on their equatorial planes. In the interior of the karyochylema the nuceoli stand out distinctly as bodies which stain much less deeply than the mass of chromatin.

The nuclei retain their characteristic structure apparently without the slightest alteration till the complete dissolution of the appendage on about the twenty-seventh day of development. When at that time the nuclei cease to stain, the chromatin [probably now of modified molecular structure] is still visible in glistening masses distributed as formerly. The nucleolus, too, is still seen as a less refractive body of greater dimensions than any of the irregular chromatin masses.

The cells of the lower part of the appendage in embryos fourteen days old [Fig. 3], do not differ in form from the ectoderm cells in general. They lengthen somewhat and clasp the inner ends of the large prismatic cells which form the great mass of the now nearly solid pleuropodium. These smaller ectoderm cells thus form a broad tubular peduncle, the lumen of which is in free communication with the body cavity of the embryo.

The next changes which may be noticed in the appendages [in embryos about nineteen days old] are superficial and easily described. The tubular peduncle increases in length with a resulting decrease in the breadth of its lumen. At the same time the portion of the segment to which the appendage is attached is carried upward and comes to lie somewhat dorsad to what will be the coxa of the metathoracic leg. While this movement is taking place a constriction appears [Fig. 6 *cn.*] dividing the bulbous mass of large prismatic cells into two segments. This constriction is merely superficial and does not divide the cells transversely. The nuclei are seen to have moved back from the periphery of the appendage and to lie, several rows deep in the basal half of the apical, and in the apical half of the basal metameres into which the organ has been constricted. The contour of the inner ends of the prismatic cells has become more distinct and the cavity into which the lumen of the peduncle opens has become larger. The peripheral ends of the prismatic cells are full of oval vacuoles of about equal size, placed side by side. They occupy the whole surface of the apical metamere. [Fig. 6 *v.*] Perhaps these vacuoles, as also those described in a preceding stage, may be caused by the action of reagents, though the regularity of their occurrence and the lack of vacuoles in other tissues of embryo *Blattæ* killed and prepared according to a method described in a former paper ['89*c*], seems to preclude the belief that they are artefacts. Be this as it may, their presence would seem to indicate that the cytoplasm of the outer ends of the prismatic cells is of a different, perhaps more sensitive, structure than that in the remaining portions of the cells.

The appendage has now reached the highest point of its development and henceforth slowly advances towards dissolution. By the twentieth day [Fig. 7] it has become more or less irregular in outline. The peduncle [*pd*], has increased in length and tenuity; the cavity [*cv.*] has become irregular owing to the basal edges of the prismatic cells becoming ragged, and the constriction is disappearing. In the appendage figured it is still seen as a deep indentation on one side [*cn.*]; on the other side no traces of it are visible. The shape assumed by the organ is now no longer constant in any two individuals. The vacuoles have either entirely disappeared as in Fig. 7, or they are much elongated and usually found between the prismatic cells. Where the lateral walls of the cells have disappeared their former position is often marked by these elongate vacuoles. From being intracellular as in Figs. 3 and 6, the vacuoles thus become intercellular just before disappearing.

On about the twenty-fourth or twenty-fifth day the cuticle covers the whole surface of the embryo. No cuticle, however, forms on the surface of the pleuropodium, the elongate peduncle of which is constricted off by the developing chitinous secretion. When embryos of this age are kept for hours or even days in hæmatoxylin or borax carmine and then washed, it is found that in perfect specimens none of the staining fluid has penetrated the cuticule; the embryo is still yellowish white, with a brilliant violet or red spot, visible to the naked eye just behind the base of the metathoracic leg on either side of the body. This is the pleuropodium, the only portion of the embryo which has been stained by such protracted immersion.

Examination with higher powers shows that the pleuropodium has now become very irregular in outline. [Fig. 8.] The old boundaries between the prismatic cells have disappeared. The apical part of the appendage, still somewhat bulbous in shape, is a syncytium through which the nuclei appear to be migrating toward the opening of what was formerly the peduncle but which has now broken down into a mass of cells of more or less irregular outline [Fig. 8 *n*.]. This mass of cells is augmented by the nuclei which are continually leaving the bulbous mass of protoplasm, and which, before they leave it, surround themselves with an irregular body of cytoplasm cut from the large mass of protoplasm. This process continues while the whole mass of cells takes on various forms. Finally it spreads out between the posteriorly directed metathoracic leg and the ventral face of the abdomen. Fig. 9 shows a section through the remains of the pleuropodium of an embryo twenty-six days old. The nuclei fail to stain more deeply than the protoplasm. The mass *pl* seems to be the remains of the bulbous portion marked *pl* in Fig. 8. In embryos a few hours older no traces of the organ are to be found. Its remains probably become indistinguishable from the granular plasmatic secretion which is found in coagulated masses about the legs and mouth-parts of the embryo. This granular plasma was originally the limpid fluid that filled the cavity of the amnion.

It will be seen from my description that the origin, development and dissolution of the pleuropodia is comprised within the space of fifteen days — from the twelfth to the twenty-seventh day of the whole period of development, which requires about a month. Within these fifteen days falls the peculiar phenomenon of revolution, which begins on the fifteenth and is concluded on the seventeenth day. Fig. 1 illustrates the lateral view of an embryo during revolution. [Sixteen days old.] The appendage [*ap*.] has reached its maximum size and already shows the constriction which is most marked a few days later. The amnion and serosa have ruptured and are passing back over the large mass of yolk. The serosa, *s*, with its large flat nuclei is contracting away from the ventral and posterior portions of the yolk. The amnion, *a*, with its much smaller nuclei still covers the ventro-lateral faces of the egg in continuity with the edge of the dorsad growing body-wall.

For a more complete account of the revolution of the embryo I would refer the reader to a former paper ['89*c*].

Periplaneta orientalis. L.

(Plate II, Fig. 10.)

So great has been the difficulty encountered in removing the large eggs of this Blattid from the thick-walled ootheca in which they are deposited, that I have succeeded in securing only a few advanced embryos.

As would be expected from the close systematic affinities of the insects, the pear-shaped pleuropodia are similar to those of *Blatta*, though they are somewhat more truncated at their ends and attached by much shorter and broader peduncles than in the species dealt with above. Fig. 10 represents a longitudinal section through one of these appendages as it appears in a cross section through the middle of the first abdominal segment. The greater portion of the body is still filled with yolk [not seen in the figure], while a portion of the mesoderm has been converted into connective tissue, *ms.* The pleuropodium is undergoing degeneration. We have seen that in *Blatta* the nuclei of the huge cells so characteristic of the organ are at first distal in position, but that they gradually wander back towards the body during the breaking down of the appendage (Fig. 8). A like migration of nuclei seems to occur in *Periplaneta,* though I cannot affirm this with certainty as I have seen only pleuropodia in the stage figured. Certain it is, however, that many of the nuclei lie in the proximal ends of the cells. The shape of cells so closely applied to one another as those under consideration must be determined to some extent by the position of their large nuclei. Now in Fig. 10, the broad ends of the cells are directed towards the body, while the narrow ends converge at a point [*t*] in the distal end of the appendage. This is probably not the original arrangement, which would be like that seen in *Blatta* [Fig. 3]. In order to reach the condition of the advanced pleuropodial cells of *Periplaneta,* from the condition seen in *Blatta* in a younger stage, we have only to suppose that most of the nuclei migrate to the proximal ends of their respective cells and push before them a quantity of protoplasm; in this way the cells would become rounded off at what were originally their pointed ends, and taper to thread like points at what were before their broad distal ends. At *x* two such cells are seen in the act of loosening themselves from the main mass and are apparently about to pass into the body cavity through the broad lumen of the peduncle. The cells with more deeply stained nuclei at *y*, agreeing with the cells of the ectoderm, *ecd*, and contrasting with the large pleuropodial cells, seem to belong to the common ectoderm; they at first, perhaps, form the walls of the peduncle but subsequently pass up into the appendage. This supposition is rendered more probable by their peripheral position. The ends of the large cells are frequently filled with and separated from one another by vacuoles, some of which are very large and conspicuous. The protoplasmic reticulum in the neighborhood of these vacuoles has the striated appearance described above for *Blatta.* At the distal end of the pleuropodium the protoplasm is less compact and in many of my sections, like the one figured, spreads out in an irregular granular mass which leaves the appendage and probably joins the amniotic coagulum. If my interpretation of the few stages which I have seen is correct, the pleuropodia of *Periplaneta* disappear partly by absorption into the body of the embryo and partly by the dissolution of their outer portions between the body walls and the egg-envelopes. In the section figured the cuticle [*ct*] is formed on the pleural and ventral walls of the abdomen, but is not continued over the surface of the pleuropodium.

Mantis carolina, L.

(Plate II, Fig. 11.)

Mr. T. H. Morgan has kindly sent me some of the embryos of this interesting insect. All the specimens examined were in a stage just preceding the rupture of the embryonic envelopes, hence almost corresponding with the *Blatta* embryo figured (Fig. 1). The pleuropodia are distinctly visible in surface view as a pair of narrowly pyriform evaginations, partly covered by the metathoracic legs with which they are homostichous. Their tips are directed laterally, while the ends of the metathoracic appendages converge towards the median ventral line. Each pleuropodium is very much shorter and narrower than the legs or any of the cephalic appendages. A section [Fig. 11] shows that the organ is a solid body, perhaps best described as a narrow, pear-shaped sack, whose thickened walls are made up of a single layer of cells and whose cavity has been reduced so as to be represented by a line. The cells forming the appendage have the form of curved pyramids; their broad bases form the outer surface and their gradually tapering apices converge from all sides towards the central line representing the obliterated cavity. These cells differ only in shape from those of the ectoderm of the body walls and other appendages: the size and reactions of the nuclei together with the quantities of cytoplasm surrounding them are essentially the same in the elements of both the body walls and pleuropodia. In the pleural wall [*ecd*] the nuclei are arranged in about three irregular rows; just at the insertion of the pleuropodium, however, there is only one row, a fact indicating that the appendage, which was very probably hollow in a preceding stage, had its lumen shut off from the body cavity by the intrusion of a layer of ectoderm cells at x. Not having studied more advanced embryos, I am unable to state anything in regard to the manner in which the pleuropodia degenerate. The fact that these organs are small and solid and that their component cells differ in no way from the ectodermic elements of the body walls and other appendages, is sufficient proof that the pleuropodia of *Mantis* are mere rudiments.

In *Mantis carolina* there are distinct appendages on at least the second, third and fourth abdominal segments, but none of these in my embryos had developed beyond the mammillate stage. *Graber* ['88] has observed on the second abdominal segment of an European *Mantis* a pair of appendages shaped very much like the pleuropodia on the basal segment. As these do not occur in all embryos of the European species, and as the embryos of the American species examined by me, were all taken from a single capsule and hence deposited by a single female, I cannot feel certain that this second pair of pleuropodia is always or even normally absent.

Xiphidium ensiferum, Scud.

(Plate 2, Fig. 12, 13, 14.)

The ontogeny of this interesting insect presents a remarkable and apparently isolated retention of many annelid traits. Among other pecularities there is developed in an early stage a large and rounded preoral disk between the procephalic lobes, making the head of the embryo resemble a clover leaf. This preoral disk is soon completely constricted off from the body of the embryo proper, and, moving forward a short distance, gives rise to two cellular envelopes. The movements of the embryo in relation to the yolk also differ markedly from anything heretofore described in insect development. As I shall devote a special paper to a description of the development of the *Xiphidium* embryo, I will here confine my attention to the pleuropodia which are quite as prominently developed as in other Orthoptera.

The embryo when first formed on the convex surface of the curved elongate-oval egg, resembles very closely the *Blatta* embryo which I have figured in a corresponding stage ['89*c*, Plate XVII, Fig. 45]. The appendages of the first abdominal segment arise as in *Blatta*, but as soon as the differentiation of their component cells sets in, a great difference between the Blattid and Locustid pleuropodia becomes apparent. Each of the modified appendages becomes bulbous and constricted into a peduncle at its base; the contôur, however, is not evenly rounded but somewhat angular. The distal end of the sack terminates in a point. Sections show that the cavity of the organ is very large [Fig. 12, *cv.*] while the cells forming the walls are consequently reduced to short and broad prisms. Their cytoplasm, though still distinctly granular, is paler than that of the ectoderm cells of the thoracic appendages and body walls. The nuclei, too, stain much less deeply than the much smaller nuclei of the remaining ectoderm, presumably because the quantity of cytochylema is relatively much greater, while the amount of chromatin in the modified and unmodified ectoderm remains approximately constant. At first the large cavity of the pleuropodium communicates with the body cavity by means of a canal through the peduncle; later this communication seems to be completely cut off by the disappearance of the lumen.

While the cells of the pleuropodia are differentiating to reach the stage figured [Fig. 12] and described, the embryo passes through the yolk backwards and emerges tail first on the concave surface of the egg. Here it grows considerably and then during revolution passes around the posterior pole of the egg and again makes its appearance on the convex surface of the yolk. During the time that the embryo is going through these peculiar maneuvers, the pleuropodia reach their maximum size and advance towards the pleuræ. Henceforth they diminish in size while their peduncles become thinner. The oldest embryos examined had their eyes pigmented and were ready to escape from their envelopes. When the chorion was removed, the serosa and first cuticle were found covering the embryo, the hypodermis of which had already secreted a second chitinous layer. The shrunken but still conspicuous pleuropodia were attached to the pleuræ laterad and close to the insertion of the saltatorial leg. A dark brown granular substance was collected in large masses over the head of the embryo, in the spaces betweeen the legs and the envelopes and on the surface of the pleuropodia, both of which were easily torn from the body and left adhering to the serosa and first cuticle. To these membranes also adhered much of the granular dark brown secretion. When I attempted to stain embryos still in possession of their pleuropodia, I made the same observation as on *Blatta* embryos of the corresponding stage: the pleuropodia were colored but the chitinous covering of the remainder of the body prevented the stain from entering the subjacent tissues. Sections through the first abdominal segment of embryos in this advanced stage [Figs. 13 and 14] show that the peduncle of each pleuropodium is much attenuated and inserted *on* the cuticle at the bottom of a rather deep pit in the pleural hypodermis [*ecd.*]. The appendage is therefore cut off from the living tissues of the body and, being very loosely attached, is easily shed by the embryo during the movements preparatory to hatching. A section through the broad portion of the organ in the present stage [Fig. 14] when compared with a section of the organ in its prime [Fig. 12] shows the extent of dissolution. The cell boundaries, faint but still perceptible in Fig, 12, have now disappeared and the organ has become a syncytium. Those portions of the cytoplasm which border the central cavity [*cv.*] are filled with numerous vacuoles of different sizes. The nuclei have lost their regular arrangement, and in many cases also their evenly oval contours; their cytoplasm stains more deeply and their chromation is aggregated to form larger masses. The granular secretion [*s*] surrounding the organ and filling such spaces as are left between the embryo and its envelopes stains deeply in hæmatoxylin and seems to be a later formation than the homogeneous secretion indicated at *as* in Fig. 12, between the amnion and body of the younger embryo. The abundance of this granular substance clinging to the walls of the shrunken pleuropodia and heaped about the legs in the immediate vicinity would seem to indicate that it is to be regarded as a secretion of the pleuropodia or of one of the embryonic envelopes and not as the decomposed amniotic secretion.

Cicada septemdecim. Fabr.

(Plate 3, Figs. 19 and 20.)

Most entomologists are familiar with the small ova deposited by this noxious Homopteron in short parallel rows in the twigs of our native trees. The eggs are translucent, so that the stages of embryos killed in Carnoy's fluid heated to 70° C., which renders the yolk transparent and the embryo opaque white, may be readily recognized before sectioning. It is difficult to remove the chorion without seriously damaging the egg, so that sections are best stained on the slide. The development is very much like that of *Aphis* as described by *Will.* ['88.] This need not surprise us when we stop to consider the close relationship of the Phytophthora and Homoptera.

In the earliest stage examined the embryo was found in the middle of the yolk, with the thoracic appendages just making their appearance, and the thin amnion so closely applied to the ventral plate as to be difficult of detection in some sections. The embryo is quite straight, exhibiting little of the pronounced curvature of the *Aphis* embryo.

In a later stage when the thoracic and cephalic appendages are well established, no appendages are to be observed on the abdominal segments, sections through which show that the ventral surface is very flat, without even the bulgings that have frequently been mistaken for rudimental appendages. In a cross section through the middle of the first abdominal segment [Fig. 20] there is seen at the points corresponding with the places of evagination of the metathoracic appendages of the preceding segment, a pair of ectodermic thickenings [*ap*]. The cells of these thickenings as shown by the curvature of their nuclei are aggregated somewhat like the segments of an orange. The long axes of all the ectoderm cells are in this stage directed dorso-ventrally. I have for the sake of emphasis represented the thickenings, which for reasons given below, I believe to be true homologues of the evaginated pleuropodia of other insect embryos, as paler than the cells of the surrounding ectoderm, though in reality no such differentiation has as yet set in. In the section figured a slight depression marks the convergence of the outer ends of the pleuropodial cells.

During the revolution of the embryo the pleuropodium reaches its full size and presents in section the appearance of Fig. 19 *ap*. It is easy to see how this organ originates from an orange-shaped cluster of cells like that just described. The ectodermic elements increase greatly in length and assume the form of curved pyramids with their tapering apices attaining the surface of the body and their broadened nuclear ends projecting into the body cavity. The outer and attenuated ends of the cells are uniformly hyaline and stain very faintly in borax carmine. The cytoplasm of the inner ends is granular like that of the remaining ectoderm. [*ecd.*] The nuclei of the pleuropodium seem not to differ in their finer structure from the nuclei of the general ectoderm. They are frequently triangular or violin-shaped both in the pleuropodium and in the undifferentiated ectoderm. The only difference is one of position: the nuclei of the body wall lie at right angles to their former position. A granular mass, the amniotic secretion, fills the space between the body walls and the egg membranes [*ch.*] In one place, however, this mass is replaced by one of a different nature, a glairy, homogeneous and vacuolated substance [*s*] of irregular though rounded outline, firmly attached to the attenuated tips of the pleuropodial cells. This homogeneous mass, which stains pink in borax carmine, is often more globular than as represented in the figure, and is often separated from the granular amniotic secretion by a clearly defined space, proving that one or both of the secretions contract under the influence of the reagents employed. From the constancy of its occurrence and the manner of its adherence to the outer surface of the pleuropodium, I do not hesitate to regard the homogeneous mass as a secretion of the pyramidal cells. It seems to consist of an albuminoid substance; the vacuoles which it contains may be artefacts. Not having examined it in fresh embryos, I was unable to learn anything more concerning its physical or chemical nature.

A somewhat more advanced embryo was examined in surface view after staining with Ehrlich's haematoxvlin. The presence of the pleuropodium was distincly indicated on each pleura of the first abdominal segment near the insertion of the metathoracic leg, by a clear circular area surrounded by a dark ring. The clear area I take to be the cluster of hyaline cell-tips; the appearance of a dark circle is probably due to the ectoderm cells seen in section at *o o* together with the nucleated ends of the subjacent pleuropodial cells.

In *Cicada* embryos nearly ready to hatch the pleuropodia are not to be found. The pyramidal cells grow pale and irregular, finally fall asunder and are probably absorbed. The ectoderm cells at *o o* grow over the small area formerly occupied by the hyaline cell-tips to complete the pleural wall.

Although the pleuropodia of *Cicada*, being invaginated thickenings of the ectoderm, differ considerably from the evaginated pleuropodia of the Orthoptera, I believe that I am justified in regarding both forms as homologues. The facts which make for this homology are the following:

1. The pleuropodia of *Cicada* are of purely ectodermic origin.
2. They appear only on the first abdominal segment.
3. They are at first homostichous with the thoracic and cephalic appendages.
4. Their cytological structure closely resembles that of some evaginate pleuropodia; the shapes of the component cells with reference to the surface of the body being merely reversed. Compare the pleuropodia of *Mantis carolina.* [Fig. 11.]
5. Their greatest development is attained during the revolution of the embryo.
6. They move away from the median ventral line of the embryo and take the same position on the pleuræ as the evaginated pleuropodia of the Orthoptera and Coleoptera.
7. They atrophy and disappear before the embryo hatches.

Zaitha fluminea, Say. *

[Plate 3 Figs. 17 and 18.]

Of this form I have examined only embryos in the stages immediately preceding, during, and after revolution. Just before revolution the embryo lies on one face of the yolk with its amnion and serosa in contact and not separated by a layer of the vitellus as in most of the Hemiptera whose ontogenies have been studied. Hence *Zaitha* would seem to resemble the Orthoptera and Coleoptera in its manner of embryo formation. The stages which I have studied show only the fully developed pleuropodia; I can, therefore, assert nothing in regard to the process whereby these organs originate and disappear, although their resemblance when fully formed to the pleuropodia of *Cicada* renders it highly probable that the beginning and end of their development are no less similar to those observed in the Homopteron.

In Fig. 17 I have represented half a cross-section through the first abdominable segment of an embryo during revolution. The ectoderm [*ecd*] of the dorsal surface in the neighborhood of the heart [*cb*] is much thinner than the ectoderm laterad to the large ganglion [*gl*]. In one place near the large pleural fold filled with adipose cells [*ad*] the ectoderm is greatly thickened to form a bulbous organ which is to be regarded as a pleuropodium. The cells composing it are greatly elongated, being three or four times as long as the thickest ectoderm cells of the ventral body wall. It is also seen that a great number of cells take part in the formation of the *Zaitha* pleuropodium while but very few go to make up the same organ in *Cicada*. In the water-bug the rounded inner face of the pleuropodium projects as far as the yolk and presents at irregular intervals a few flattened mesodermic elements [*cn*]. The inner ends of the long cells are coarsely granular, their outer ends uniformly hyaline. Their nuclei are but little larger than the nuclei of the body walls. The delicate hyaline cell-tips converge to form a flat surface which is covered

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* The eggs of this species were given me by Dr. W. Patten as the eggs of an aquatic Hemipteron, which from his description I took to be a *Nepa*, and mentioned it as such in my preliminary notes ('89*a* '89*b*). The species, however, can be no other than our common *Zaitha fluminea*, Say, for I now remember Dr. Patten telling me that he found the eggs attached to the hemielytra of the female. This habit, according to *Uhler* (article *Hemiptera*, Standard Natural History Vol. II, p 258, 1884) is shared, so far as their habits have been observed, by all the species of this exclusively American genus. The female *Nepa* attaches her eggs to aquatic plants. The chorion of the egg is smooth and unornamented in *Zaitha*, while the egg of *Nepa* has at one end seven hair-like radiating processes, which, according to *E. v. Ferrari*, make the egg resemble the seed of *Carduus benedictus*. (Die Hemiptren-Gattung *Nepa*, Latr (sens. natur.) Annalen d. K. K. naturhist. Hofmuseums. Bd. III, No. 2. Wien 1888.)

I hasten to correct my mistake, as the species of *Nepa* and *Zaitha* are not only generically distinct, but belong to different families: the former to the *Nepidæ*, the latter to the *Belostomatidæ*.

by a broad pencil of refractive threads [*s*] which is to be regarded as the secretion of the pleuropodial cells. In Fig. 18 three of these curious cells are represented as they appear under a magnification of about 900 diameters. The inner ends which stain deeply in borax carmine contain a number of very coarse granules among which are interspersed a multitude of finer ones; the granules diminish in number beyond the oval nuclei and have completely disappeared in the gradually tapering outer ends of the cells [*l*]. These ends are not affected by the stain. Each cell-tip is capped by a refractive thread, which nearly or quite equals the cell in length and may often be split into two or three branches. Usually the line which separates the cell-tips from the threads which cap them, is distinctly marked as in Fig. 17 and at *z* in Fig. 18. I have, however, found numerous cases where no such line could be detected, the hyaline cell-tips passing without interruption into the long refractive threads. The minute structure of the nuclei resembles that of the pleuropodial nuclei of *Blatta*. Through the faintly stainable caryochylema runs a chromatic reticulum, the nodes of which are irregular and much thickened. The nucleolus has little affinity for staining fluids and is probably to be relegated to *Carnoy's* class of "nucléoles plasmatiques."

Sialis infumata, Newm.

This Neuropteron oviposits on the leaves of plants overhanging the water. The eggs are arranged in regular rows, with their stem-shaped micropyles directed upwards. The embryos are so small that it is difficult to obtain good surface views; still I have been able to satisfy myself that the first abdominal segment, at about the time of revolution, presents a pair of conical evaginated pleuropodia, which lie somewhat outside of the line of the thoracic legs. In my sections I could detect neither a differentiation of the cells nor diverticula of the body-cavity extending into these appendages. The apparent solidity of the organ may have been due to the thickness and the plane of my sections.

PART SECOND.

Gryllotalpa vulgaris. L.

The pleuropodia of the mole-cricket were observed as early as 1844 by *Rathke* ['44] who described them as mushroom-shaped bodies. Many years later, *Korotneff* ['85] in his account of the general embryology of *Gryllotalpa* figured and described the same organs more at length. According to this author they arise as button-shaped prominences, not in line with the other appendages but laterad to them. Their outline in section resembles that of a mushroom and they are seen to consist of succulent [saftigen] cells. Later, when the back of the embryo has closed over, these appendages atrophy [" gehen zu Grunde"]. They fall off and disappear completely. [" Sie fallen spurlos ab"].

It may be doubted, judging from observations on other Orthoptera, whether the pleuropodia arise laterad to the other appendages. Probably the earliest stages in their formation escaped *Korotneff*. His last observation, viz.: that the pleuropodia fall off, is quite definite, and, if based on observation, precludes their possible disappearance by absorption.

Oecanthus niveus, Serville.

The second insect in which pleuropodia were described was *Oecanthus niveus. Ayers* ['84] while pursuing the general ontogeny of this Gryllid was evidently impressed with the interest attaching to these organs; hence the more complete account which I reproduce in full:

" The respiratory function of the embryo is first indicated at the time of revolution by the appearance of paired lateral outgrowths of the ectoderm from the pleural region of the first abdominal segment. These gills or respiratory organs come to lie just behind, but dorsad of the base of the third thoracic appendage. In outline they are broadly oval or kidney-shaped and are united to the body by a short peduncle springing from the center of that face of the disc which is in contact with the body of the embryo. These folds are cellular structures and at different periods are solid or hollow. The cells of the folds early lose their ectodermic characters and become somewhat larger than those of the adjacent body wall. In the fresh condition they appear enucleate and coarsely granular, but upon treatment with osmic or acetic acid a nucleus is distinctly visible. In surface view there is to be seen a clear central area which indicates the position of the internal cavities of the gill. These cavities are continuous with the body cavity and probably serve as channels through which the vascular fluid circulates They vary in shape and relative proportions. The relations of these appendages to the body is best seen in sections. The outgrowing flap is here seen to project over an invagination immediately below it and in some instances to become apposed so closely to the body wall as to convert the open pocket into a closed canal. In its middle part, where the fold fuses with the body, its cells are separable into two irregular layers which correspond to the two primitive plates of the fold, but they fuse completely, or become widely separated, in the free portion of the pad. These appendages reach their greatest degree of development soon after the revolution of the embryo, and then gradually atrophy, entirely disappearing before the complete closure of the body walls. In sections of the gill organ before its atrophy [or absorption] one finds both distinct canals and lacunar spaces, which radiate from the point of connection of the pad with the body, and these together with the arrangement of the cells give the radiate structure characteristic of the fresh gill. The canals are generally circular in section and pursue irregular courses throughout the cell substance, while the spaces are developed by the separation of adjacent cell walls and are irregular in outline and occur at varying distances from each other. The gill pad is essentially a single-layered sac, with a much constricted neck, evaginated from the pleural region of the abdomen. The protruding organ is flattened against the body of the embryo and by this means the cells are rendered spindle-shaped. The nucleus of each cell lies in that part of its cell which is farthest from the constriction of the organ. The cell wall gradually tapers to a point and ends near the neck. The cells are bent in various ways depending upon the relations of their nuclei to the wall of the pad."

Ayers seems not to have recognized the identity of the abdominal appendages and what he calls the "gill-pads." On plate 18 he figures [Figs. 8, 19, 20, 23, ab. p.] the first pair of abdominal appendages as digitiform and arising in a line with the thoracic and remaining abdominal appendages. In Fig. 20 these organs are seen with tips directed outward, while the ends of the thoracic appendages converge. Concerning the abdominal appendages he writes:

"Soon after the mesoderm has extended into the hollow appendages, there appear successively a varying number of abdominal protuberances exactly similar to the maxillary and thoracic appendages in their earliest stage of growth. Of these only two pairs ever reach any considerable degree of development, they are the first and the last abdominal. The former grows to the length of the mature mandibles and then atrophies. It varies in shape from a finger-like process [pl. 18, fig. 17] to a lobed outgrowth, and in the later stages is covered by the last thoracic appendage."

The last sentences imply that the organ undergoes dissolution *in situ* and this is further sustained by Fig. 22, where what would seem to be the irregular remains of the appendages are seen through the translucent metathoracic legs. Evidently *Ayers* lost sight of the appendages after they had been covered by the last thoracic legs and when they passed out from under these and made their appearance as enlarged and peculiarly modified organs high up on the pleural wall, they were regarded as organs having no relation to the abdominal appendages. *Ayers* no longer letters the appendages with ab. p., but with a new reference, λ, and, what is more conclusive, says that the pleuropodium "is essentially a single-layered sac with a much constricted neck, evaginated from the pleural region of the abdomen."

The section of the "gill" described and figured by *Ayers* [Figs. 13 and 14, pl. 22] "before its atrophy [or absorption]" shows the cells after the setting in of degeneration. The figures are in every way comparable to the figure which I have given of *Periplaneta* (see above, page 92, also fig. 19, Plate II). Fig. 14 shows the dorsal wall of the embryo covered over and the heart completed, a stage in which the pleuropodia have passed beyond their maximum development which is attained just before or during revolution. The canals and spaces alluded to in *Ayers'* description are exactly like those seen in *Periplaneta* in the corresponding stage, and must not be regarded as delicate ramifications of the body cavity but as irregular spaces produced by the falling asunder of the columnar cells. They are probably identical with the intercellular vacuoles seen in the degenerating pleuropodia of *Blatta* and *Periplaneta*. Had *Ayers* passed sections through the pleuropodia of *Oecanthus* before the setting in of dissolution, his description would have been different and very probably like what I have given for *Xiphidium*.

Stenobothrus.

Graber briefly described the pleuropodia of this Acridian in his paper on polypody ['88]. In a more recent article ['89] he gives a fuller description which I reproduce:

"Each of the pleuropodia of *Stenobothrus* at the time of its greatest development lies on the pleural wall of the first abdominal segment about where, in later life, the tympanal apparatus is situated. It is a flattened biscuit-shaped body about 1 mm. in diameter. While the remainder of the body wall remains destitute of pigment till the insect hatches, the pleuropodia acquire a brownish hue. Of the same color also is a finely granular coagulum partly glued to the skin in the immediate neighborhood of the pleuropodia and the legs. In sections the organs present a wide cavity which opens by means of a short and rather broad passage into the body cavity. In some sections a few cells, probably interpretable as blood corpuscles, are to be found in the cavity; in other sections these cells are absent. The large cells of the outer wall, which in this insect also are enormously developed, are especially interesting, as they are so filled with yellowish granules that the whole outer wall of the sack presents the appearance of a brownish yellow plate. These granules are visible even in Canada balsam preparations. Closer observation shows that the above mentioned coagulum in the vicinity of the pleuropodia and legs contains yellow granules very similar to those contained in the cells and thus justifies the conclusion that this coagulum, at least in part, is secreted by the pleuropodial cells, the outer surfaces of which are not covered by a chitinous cuticle."

Blatta germanica, L.

Patten was the first investigator to describe the pleuropodia of *Blatta germanica* ['84]. His observations are summed up in the following words:

"At first a number of abdominal appendages are developed which, however, quickly disappear again with the exception of the first pair, which further develops into pear-shaped structures attached to the abdomen by a stem that increases in length and finally changes into a very fine duct leading into a small cavity in the expanded distal extremity, which owes its size to the development of extremely high ectoderm cells. No mesodern enters into the construction of the peculiar organ which in the later stages of development disappears entirely."

Cholodkovsky's paper ['89] which in respect of the pleuropodia of *Blatta* adds but little to *Patten's* description, appeared several months after my account of these organs was written. After describing the origin of the different appendages, the Russian observer passes to a more detailed description of the first abdominal pair.

" While the ectoderm cells keep increasing in length in the first abdominal appendages, those of its constricted basal portion, on the contrary, become somewhat shorter. As a consequence of these changes the abdominal appendage assumes the shape of a pear attached to the body by means of a slender stem only. The greater portion of such an appendage consists of very long and narrow, almost fusiform ectoderm cells, which with their broadening distal ends form the surface of the appendage, while their proximal ends narrow towards the peduncle. The cells are very closely applied to one another, and there is no cavity in this portion of the modified appendage, though there is a narrow canal in the axis of the peduncle leading into the body cavity. Somewhat nearer its distal than proximal end each long ectoderm cell contains a large oval nucleus. Focussing on the surface of the widened portion of the pear-shaped body one observes that it is divided into facets; each facet has slightly raised edges and a central depression, and belongs to an ectoderm cell. During later development before the hatching of the embryo these appendages disappear by a process unknown to me."

This description is in the main correct. It is true that the outlines of the pleuropodial cells are polygonal in surface view, but I have never seen anything like the facets with raised edges and depressed centers described by *Cholodkovsky* and depicted in his Fig. 15 This appearance is probably due to *Cholodkovsky's* method of preparing *Blatta* embryos by protracted immersion in Perenyi's fluid, a method which is in all probability responsible for the marked distortion of some of his other figures.

Mantis.

To *Graber* we owe the only account of abdominal appendages in *Mantis* embryos published heretofore. In his general work on insects ['77] he figures the anterior portion of a young *Mantis* embryo, in which the pleuropodia are seen as a pair of digitiform processes, directed and shaped like the thoracic legs, which they are far from equalling either in length or breadth. In his later paper ['88] *Graber* figures another embryo *Mantis* in which is seen a pair of what might be called secondary pleuropodia on the second abdominal segment. This second pair, which is absent in some embryos is somewhat smaller, though in other respects exactly like the first pair. Further stages in the development of these organs are not described.

It is probable that they soon disappear without ever becoming bulbous, since a tendency thus to differentiate is distinctly manifest in other Orthopteran embryos that have reached the age of the *Mantis* embryos figured by *Graber*.

Neophylax concinnus.

An isolated observation on pleuropodia in the Phryganeidae is embodied in one of *Patten's* figures of a *Neophylax* embryo ['84, plate 36 A, Fig 11.] *Patten* notes the fact in the text [page 578] that three pairs of abdominal appendages are developed on the basal segments, but says nothing about a differentiation of the most anterior pair. The figure referred to, however, shows that the conical abdominal appendages of the first abdominal segment are considerably larger than those of the two succeeding segments. Dr. Patten has, at my request, kindly taken the trouble to re-examine his sections, and informs me that the cells of the pleuropodia differ in structure from the unmodified ectoderm cells of the other appendages and the body wall of the embryo.

Acilius.

At my request, Dr. Patten has very kindly sent me the following description of the pleuropodia of this Dytiscid:

As in other forms so in *Acilius*, the pleuropodia arise on the first abdominal segment of the young embryo, as a pair of ectodermic evaginations, homostichous with the thoracic legs. Later, the distal end of each bulbous appendage, consisting of large columnar cells, is invaginated in the form of a cup. The nuclei are situated in the inner ends of the cells, each of which secretes at its tip a short refractive thread, which, with those of the neighboring cells goes to form over the invaginated area a thick, striated, cuticula-like layer. Dr. Patten remarks that this form of secretion may be compared with the pleuropodial secretion of *Zaitha*, the only difference being that the individual threads secreted are so short as to form together a continuous sheet, instead of a penicillate bundle.

These peculiar appendages, which of all described species most closely resemble the pleuropodia of *Meloe*, do not fall off during their period of degeneration, but are pushed into the yolk and absorbed.

Hydrophilus piceus, L.

The pleuropodia of this form were first observed by *Kowalevsky* [71.] They are distinctly seen in his Fig. 12, as digitiform processes, shorter than the metathoracic legs. Nothing is said of their differentiation. In the figure of an older embryo they are represented as a pair of smaller protuberances inserted on the pleurae near the bases of the metathoracic legs.

Heider ['89] in the first part of his beautiful monograph, figures the pleuropodia of *Hydrophilus* in several places, [Figs. 2 and 3 in the text;

Fig. 9, plate 2, Figs. 10a, 10b, 11 and 12, plate 3] not as digitiform, but as small bulbous organs with spherical contour, developed from a pair of small mammillar prominences. At the time of the rupture of the embryonic envelopes, they are but little larger than the terminal metameres of the metathoracic legs and show but little tendency as yet to move apart from the places where they arose in line with the metathoracic and remaining abdominal appendages. In sections of the last stages described by *Heider*, the beginning of a differentiation of the cells may be observed but the pleuropodia do not attain their greatest differentiation till a later stage of development. *Heider* reserves further description for the second part of his monograph.

Melolontha vulgaris, Fabr.

In the cockchafer the pleuropodia attain a much greater size than in any other insect heretofore studied. We are indebted to *Graber* for an excellent description of these remarkable organs. ['88.]

The pleuropodia are first seen in embryos twelve days old, and do not reach their maximum size till the twenty-second day. They are large flattened sacks attached by peduncles and, when fully developed, are much longer than the thoracic legs and about three times as broad. *Graber* thus describes the minute structure of the full-grown pleuropodium:

"In respect of histological structure, a feeble magnification shows that the condition of the abdominal appendages differs decidedly in many, if not in all, particulars from that of the legs. This is especially true of the outer, or ectodermic layer. For, while this layer in the legs, like that of the body wall and all the other appendages * * * * consists of relatively narrow cells with relatively very small [0,006 mm] nuclei and only sporadically inserted larger cells with large nuclei, nearly all the cells in the abdominal appendages, and more especially those forming the outer walls of these pocket-shaped organs, are of considerable size and are provided with nuclei more than twice as large as those of the remaining ectoderm, since they measure about 0,014 mm. Considering that, at the time when the organ was formed, the ectoderm nuclei were 0,008 mm in diameter, it follows that during the course of further development, the nuclei of the ordinary ectoderm become somewhat smaller, while those of the ectoderm of the abdominal appendages undergo a considerable increase in size. This increase is most pronounced in the outer wall of the appendage; a portion of the inner wall, as well as the short cervical portion, or peduncle, formed by constriction, having typical [i. e., small] ectodermelements." Within the cavity of the sacks "are found numerous cells of the same structure as those which occur in the body cavity and likewise in all the appendages. I regard it as an open question whether these elements, originating as they do from an evagination of the mesoderm, become wholly dissociated and are ultimately to be regarded as blood cells, or whether they, in part at least, unite to form a loose tissue [lockeres Gewebe.]"

Graber has also observed the atrophy of the pleuropodia of *Melolontha*. Degeneration begins about eight days after the pleuropodia attain their maximum size. "In the embryo thirty days old, with the dorsum closed over and the cephalic and anal ends already strongly flexed towards each other, the organ has diminished in size, not only when compared with the legs, but absolutely. More striking, however, is the reduction of the abdominal appendages in the thirty-four day old embryo, which in consequence of its great increase in length, is already completely coiled up and has attained to maturity. Here the appendages in question, are nothing but minute scales, hardly as long as a segment, and half concealed in the aforementioned coagulum. They separate from the body with the slightest touch. Probably they are pushed off while the insect is leaving its envelopes, perhaps in consequence of rubbing against the same. In the hatched larva only the healed [verloethete] cicatrice of the peduncle is to be found."

Meloe proscarabœus. L.

After treating of the formation of the germ-layers of this Coleopteron in a former paper, *Nusbaum* devotes a more recent article ['89] to a description of the very interesting pleuropodia. I quote his description *in extenso:*

"The appendages of the first abdominal segment have up to the eighth day of development the form of roundish cylindrical sacks and consist, like the thoracic legs, of a single layer of cylindrical ectoderm cells surrounding a cavity in which may be seen a few loose mesoderm cells. On the eighth day of development each of these appendages differentiates into two parts: one basal and cylindrical, and one distal, which is spherical and somewhat pointed at the pole [outer end]. In the basal part the cavity persists as before, together with the loose mesoderm cells; in the spherical portion, however, the cavity disappears and is replaced by large and much lengthened cylindrical cells. These large cells arise by a kind of invagination of a portion of the ectodermic layer at the pole of the appendage. The cells of the invaginated portion grow very rapidly and soon take on the appearance of very large and characteristic elements, so loosely juxtaposited that narrow clear slits may be observed here and there between them. The edges of the invagination approach one another till there remains only a small aperture leading into a roundish cavity closed on all sides. On the tenth day of development the segmentation of the thoracic legs may be seen very distinctly; in each leg three to four parts, or segments may be distinguished, which are marked off by constrictions on the outer surface of the ectoderm. It is interesting to note, that the appendages of the first abdominal segment seem also to undergo a kind of constriction, so that I cannot concur in *Graber's* statement that "the abdominal appendages are always unsegmented." For, in the above mentioned stage of development a distinct constriction of the ectoderm may be observed between the basal and distal portions; hence I believe that we are justified in regarding as segments the two parts of the appendage thus distinctly separated. On the twelfth day of development — sometimes even before — the plasma of the invaginated cells, whose roundish oval nuclei lie near the basal ends, acquire a very distinctly and finely fibrillar structure, resembling that of the epithelium of many excretory glands. In the above described cavity is collected a homogeneous, sticky secretion, which gradually swells out of the aperture in considerable quantity. It is easy to detect delicate threads of this secretion running from the large cells surrounding to the mass of the secretion filling the cavity. The structure of these glandular appendages reminds me somewhat of the glandular temporary appendages ['dorsal organ'] which I have described in *Mysis;* I hasten, however, to state expressly that I do not wish to maintain any homology between these organs."

Interesting as is the account just quoted, *Nusbaum* goes on to describe a still more interesting condition. He says: "I have further convinced myself that the remaining stub-shaped abdominal appendages of *Meloe* are of a glandular nature. At the tip of each of these appendages there is also formed an invagination, which is, however, much shallower than in the appendages of the first abdominal segment, so that it does not form a cavity. The invaginated cells are closely juxtaposited, long and cylindrical but not as large as those of the first abdominal appendages. They likewise secrete a sticky substance, though in less quantity than the afore mentioned organs of the first segment. Back of these invaginated cells lies a cavity communicating with the body cavity and filled with loose mesoderm cells." The further fate of these organs was not traced by *Nusbaum.* "The roundish terminal joint of the appendages of the first abdominal segment is very probably thrown off, while the basal portion together with the stub-shaped appendages of the other abdominal segments gradually grow shorter, flatten out and finally disappear entirely."

Before passing to a brief resumé of the results recorded in the preceding portions of my paper, I insert a table of the insects, which have been studied with reference to abdominal appendages. In this list are included a few forms, in which no pleuropodia have been described. I am well aware that negative conclusions in regard to details merely read between the lines of works on the general ontogeny of a species are of very little value, but in the cases to which I allude, the probability of such prominent organs as the pleuropodia being overlooked by investigators who have carefully studied insect embryos by means of sections is so small, that I do not hesitate to record their omissions as negative results. Most of the forms enumerated as having no pleuropodia were examined by *Graber* and myself with the express purpose of observing whether these organs were present.

ORDER ORTHOPTERA.

FAMILY GRYLLIDÆ.

Oecanthus niveus, Serville.

pleuropodia evaginate, bulbous with reniform outline. [*Ayers* '84.]

Gryllotalpa vulgaris, L.

pleuropodia evaginate, bulbiform. [*Rathke* ('44), *Korotneff* ('85), *Graber* ('88).]

FAMILY LOCUSTIDÆ.

Xiphidium ensiferum, Scud.

pleuropodia evaginate, bulbiform, subreniform [*Wheeler*].

FAMILY ACRIDIIDÆ.

Stenobothrus.

pleuropodia evaginate bulbiform, with yellow granular secretion. [*Graber* ('88,) ('89)].

FAMILY MANTIDÆ.

Mantis (European).

pleuropodia evaginate digitiform; occasionally a pair on the second abdominal segment [secondary pleuropodia] [*Graber* ('77), ('88)].

Mantis carolina, L.

pleuropodia evaginate, elongate pyriform [*Wheeler*].

FAMILY BLATTIDÆ.

Blatta germanica, L.

pleuropodia evaginate, broadly pyriform. [*Patten* ('84,) *Cholodkovsky*, ('89,) *Wheeler.*]

Periplaneta orientalis, L.

pleuropodia evaginate, pyriform [*Wheeler*].

ORDER HEMIPTERA.

FAMILY APHIDIDÆ.

No pleuropodia described for any of the following species:—

Aphis pelargonii.	[*Will* ('88).]
" *saliceti.*	[*Will* ('88).]
" *rosœ*, L.	[*Will* ('88).]

FAMILY CICADIDÆ.

Cicada septemdecim. L.

pleuropodia invaginate, solid, bulbiform, with glairy, vacuolate secretion. [*Wheeler* ('89a, and '89b)].

FAMILY BELOSTOMATIDÆ.

Zaitha fluminea, Say.

pleuropodia invaginate, solid, bulbiform, with penicillate secretion. [*Wheeler* ('89a and '89b),].

ORDER COLEOPTERA.

FAMILY HYDROPHILIDÆ.

Hydrophilus piceus, L,

pleuropodia evaginate, digitiform. [*Kowalevsky* ('71). *Heider* ('89)].

FAMILY DYTISCIDÆ.

Acilius.

pleuropodia evaginate, calyculate, with a thick, striated, cuticula like secretion. (*Patten.*)

FAMILY SCARABÆIDÆ.

Melolontha vulgaris, Fabr.

pleuropodia evaginate, very large, flattened, bag-shaped [*Graber* ('88)].

FAMILY MELOIDÆ,

Meloe proscarabœus, L.

pleuropodia evaginate, calyculate, with sticky homogeneous secretion. [*Nusbaum* ('89).]

FAMILY CHRYSOMELIDÆ.

Lina tremulæ, Gmel.

no pleuropodia [*Graber*].

Doryphora 10-*lineata*, Say.

no pleuropodia [*Wheeler* '89].

ORDER NEUROPTERA.

FAMILY SIALIDÆ.

Sialis infumata, Newm.

pleuropodia evaginate, conical (*Wheeler*).

ORDER TRICHOPTERA.

FAMILY PHRYGANEIDÆ.

Neophylax concinnus.

pleuropodia evaginate, conical [*Patten* ('84)].

ORDER LEPIDOPTERA.

FAMILY BOMBYCIDÆ.

No pleuropodia have been observed in the following: —

Gastropacha quercifolia, L.	[*Graber* '88.]
Bombyx mori, L.	[*Tichomiroff* ('82)].
Orgyia leucostigma, A. and S.	[*Wheeler.*]
Telea polyphemus, Cram.	[*Wheeler.*]
Callosamia promethea, Drury.	[*Wheeler.*]
Platysamia cecropia, L.	[*Wheeler.*]
Hyperchiria io, Fabr.	[*Wheeler.*]

ORDER DIPTERA.

No pleuropodia have been observed in the following:—

FAMILY CHIRONOMIDÆ.
Chironomus. [*Weismann*, ('63).]

FAMILY TABANIDÆ.
Tabanus atratus, Fabr.? (*Wheeler.*)

FAMILY MUSCIDÆ
Musca [*Weismann* ('63), *Voeltzkow* ('89)].

ORDER HYMENOPTERA.

FAMILY APIDÆ.
Apis mellifica, L.
No pleuropodia [*Buetschli* ('70), *Grassi* ('84).]

The facts accruing from a study of the pleuropodia in the above enumerated forms, representing some of the families of most of the natural orders of insects, may be briefly summarized as follows:

1. The pleuropodia were at one time organs of considerable functional importance to the primitive Hexapoda. This is proved both by the size which they attain in several cases [*Melolontha*, *Blatta*, *etc.*] and by the variety of structure which they exhibit in different species, sometimes even of the same natural order [*Hydrophilus*, *Melolontha*, *Meloe.*] The latter fact would indicate that the organs had occurred very generally among ancient insects and had undergone the modification to which the struggle for existence subjects organs of very general occurrence and important function.

2. Pleuropodia seem to be of constant occurrence in insects of some orders [Orthoptera, Trichoptera (?)], in other orders these organs are as constantly wanting [Lepidoptera, Hymenoptera], while in still other groups [Coleoptera, Hemiptera] they are well developed in some forms and entirely lacking in others.

3. The pleuropodia are always derived from the ectoderm.

4. They arise as appendages serially homologous with the appendages of the thorax and abdomen.

5. The pleuropodia described up to date belong to one of two types—they are either formed by evagination or invagination. Those of the latter type are subspherical and solid; those of the evaginate type appear under two forms: the bulbous and the calyculate, the latter being distinguished from the former by having the apical area invaginated. [*Acilius*, *Meloe.*] The evaginate bulbous form undergoes some modification in different species. Thus we may distinguish as its varieties the mushroom-shaped [*Gryllotalpa*], the reniform [*Oecanthus*], the broadly pyriform [*Blatta*], and the elongate pyriform pleuropodium [*Mantis carolina*]. All these varieties

are pedunculate. Undeveloped pleuropodia do not become bulbiform, since they never pass beyond the conical or digitiform phases common to all incipient insect appendages. [*Neophylax.*]

6. The cells composing the pleuropodia in all cases except where these organs remain rudimentary or digitiform, deviate considerably in their structure from the ectoderm cells of the body wall and the other appendages. The cells and nuclei increase in size and usually become more succulent.

7. In most pleuropodia of the evaginate type there is a larger or smaller cavity, communicating by means of a narrow duct through the peduncle with the body cavity [*Blatta*, etc.]. In the calyculate forms there is a second cavity, distinct from the first, opening in the opposite direction, on the outside of the body.

8. No tracheæ, nerves or muscles have been observed to enter into the formation of the pleuropodia. A few mesoderm cells, probably blood-corpuscles or fragments of mesenchymatous tissue, have been observed in the cavities of some evaginate pleuropodia.

9. In some species the pleuropodia produce a secretion from the ends of their enlarged cells. This secretion may be a glairy albuminoid substance [*Cicada*, *Meloe*,] a granular mass [*Stenobothrus*], a bundle of threads [*Zaitha*], or a thick, striated, cuticula-like mass (*Acilius*).

10. In some evaginate pleuropodia there appears a constriction, probably homologous with some one of the constrictions which separate the thoracic and maxillary appendages into metameres.

11. In some cases, at least, no chitinous cuticle is formed over the surface of the pleuropodial cells. [*Blatta*, *Stenobothrus.*]

12. The pleuropodia attain their greatest size during the revolution of the embryo. Soon after the yolk has been enclosed by the body walls and the heart has formed, the appendages of the first abdominal segment begin to degenerate.

13. The degeneration of an evaginate pleuropodium does not in all cases result in a reabsorption into the body of the embryo, but in a falling assunder of its large cells and their subsequent dissolution outside the insect's body.

14. The pleuropodia in all their forms and stages are characterized by a certain incompleteness, which, together with the brevity of their existence even during embryonic life, stamps them as mere rudiments of what were probably in remote ages much larger and more complex organs.

PART THIRD.

The question as to the original function of the pleuropodia must needs have suggested itself to all investigators who have met with these conspicuous organs in insect embryos. Naturally enough, each investigator has sought an answer in the particular insect studied, in most cases never suspecting that so simple an organ as a pleuropodium could have undergone much modification and have assumed in forms unknown to him a structure calculated to render his narrowly based theoretical conclusions untenable. In view of the ectodermic origin of the pleuropodia, they may be said to have had one of three functions: they were either respiratory organs, sense organs or glands. Hence, owing to the fact that limited observation has precluded any general survey of the pleuropodia throughout the whole Hexapod group, different investigators have advocated one or the other of these functions, each being guided to his particular view by the special insect to which he devoted his attention. Thus *Graber* has become an advocate of the gill hypothesis from his observations on *Melolontha*, a form in which the pleuropodia are in many ways singularly specialized; *Cholodkovsky*, perhaps impressed by what he supposed to be a facetted surface on the pleuropodia of *Blatta* — in reality a phenomenon due to his use of reagents — believes the pleuropodia to be sense organs; while *Nusbaum* has been most naturally led to regard the modified appendages as glandular organs by his observations on *Meloe*.

I shall proceed to a consideration of the three theories advocated up to date, briefly examining into the reasons which have influenced their adherents, and finally settling on the gland theory as to me the most probable. With this last theory none of the observed facts are in contradiction — while as much cannot be said of the gill and sense organ hypotheses.

A. *The Gill Hypothesis.*

Rathke, the first to find pleuropodia, was also the first to assign to them a function ['44]. Their peripheral position, the delicacy of their surfaces, their close adherence to the egg-membrane, which he thought due perhaps to some sticky substance, and the further fact that they contained cavities filled with what was very probably blood, made *Rathke* believe that he was dealing with respiratory organs. He supposed, moreover, that these organs functioned during embryonic life. The embryos of *Gryllotalpa*, he says, require a great deal of air, on which account they are deposited in spacious subterranean chambers. When simply buried in the earth, the eggs decay.

Ayers followed *Rathke* in his interpretation of the problematic appendages. ['84]. Of late *Graber* ['88] though dealing with these organs at greater length, and possessing more facts than his predecessors, has adopted their theoretical views without modification. His latest contribution, however, seems to show a tendency to depart from the standpoint held in his paper on polypody, a change of opinion attributable to his study of *Stenobothrus.*

The facts which have led to the assumption of the gill hypothesis are the following:

1. The position of the pleuropodia on the pleuræ near the insertion of the metathoracic legs could not fail to suggest the respiratory organs of the Crustacea.

2. In some insect embryos the pleuropodia are shaped like lamellar gills. This is notably the case in *Melolontha,* the pleuropodia of which are so gill-like that *Graber* figures an Isopod side by side with the insect embryo for the sake of comparison.

3. Blood has been observed to circulate in and out of the pleuropodia.

That these facts are not sufficient to sustain the hypothesis, is shown by the following consideration:

The pleuropodia of *Melolontha* certainly resemble the gills of certain Isopoda, but it is almost equally certain that the appendages of the cock-chafer have departed from the original type of pleuropodium which is best seen in the Orthoptera [*Blatta, Stenobothrus*]. As these organs were present after hatching, in ancestral forms, it follows that in the precursors of *Melolontha,* they might have been balloon-shaped after the animal's escape from the egg. Such large, sack-shaped organs must necessarily become much flattened while they are confined to the narrow space between the body-wall of the embryo and the egg-envelopes.

The cell-layer forming the walls of the pleuropodia in all cases where these organs are not rudimental, is considerably thicker than the ectoderm of the appendages and body walls. Now, as a gill in ultimate analysis is merely a thin layer of cells separating the blood from the air, it becomes very difficult to understand why the comparatively thin layer of ectoderm cells forming the walls of the thoracic and cephalic appendages and the integument in general should not constitute a much more efficient respiratory organ than the thick-walled pleuropodia.

Blood has been seen to circulate in and out of the pleuropodia, but it also circulates in and out of the legs, mandibles, anal stylets, etc., in the same manner.

The bulbous shape of the pleuropodia in the majority of forms is unlike that of any known insect gills. The tracheal gills seen in the larval Ephemeridæ, Odonata, etc., are foliaceous or filamentous; while the protrusile, anal gills of such forms as the larval *Eristalis* are tubular.

Lastly, appendages shaped like the pleuropodia of *Meloe, Acilius, Zaitha* and *Cicada,* could not have had a respiratory function. The hypothesis is therefore insufficient to cover all the facts and must be either restricted to a few doubtful cases or abandoned altogether.

B. *The Sense-organ Hypothesis.*

Patten ['84] and *Cholodkovsky* ['89] are the only investigators, who have maintained that the pleuropodia of embryo insects may have functioned as sense organs. The following facts make for the probability of this supposition:

1. The pleuropodia are composed of peculiarly modified ectoderm cells.

2. They roughly resemble such sensory structures as the Arthropod eye.

3. Paired sense-organs are known to occur on the abdominal segments of many Arthropods. Cases in point are the curious *Euphausia* with its pairs of eye-like sense organs and many Orthoptera that have sensory ana stylets.

4. In *Acilius*, as Dr. Patten informs me, the small rods secreted by the pleuropodial cells are comparable to the retinal rods in the larval eye of the same insect. That the secretion in *Cicada* and *Meloe* flows together into one glairy mass, instead of forming bodies of like and definite shape capping the ends of the individual cells, may be due to the fact, that the organs are now merely rudimental structures. Dr. Patten tells me that the large lateral sense-organs of the embryo *Limulus polyphemus* produce a glairy secretion very similar to what I have described in *Cicada* ['89 a and b].

5. The pleuropodia are similar in shape and manner of development to the halteres of the Diptera and the pectinate appendages on the second abdominal segment of Scorpions, both of which modified appendages, as we have good evidence for believing, are functional sense-organs.

These facts are weighty. It seems to me, however, that the supposition that the pleuropodia are sense-organs, is untenable, for the reason that no investigator has yet observed even a trace of nervous tissue in connection with the pleuropodial cells. In sense-organs as large as the pleuropodia we should certainly expect to find a well-developed neural element, since in the case of much smaller and more insignificant sense-organs it is not difficult to detect the nervous connection. Granting that the pleuropodia are rudimental structures, it remains none the less improbable that a nervous connection, which in so large an organ must have been prominently developed at one time, could have disappeared so completely while the sensory cells themselves underwent comparatively little diminution in size. The pleuropodia are, moreover, most conveniently located for innervation from the large ganglion of the first abdominal segment or from one of its main branches.

It is, of course, possible, that in some or all forms the organs under consideration may have had a sensory function; but the facts accumulated up to the present, do not permit us to assign to the cells any other than a secretory function.

C. *The Gland Hypothesis.*

Besides *Patten*, who claimed that the pleuropodia might be glands ['84] no one till very recently has considered this view. In the July number of the American Naturalist ['89a] I advocated this view in a brief note.* In one of the August numbers of the "Biologisches Centralblatt" ['89] *Graber* published his remarks on the pleuropodia of *Stenobothrus*, attributing to these organs a glandular function. In one of the September numbers of the "Zoologischer Anzeiger" ['89b] a preliminary account of my observations on the pleuropodia of *Zaitha* and *Cicada* was published. In one of the October numbers of the "Biologisches Centralblatt" appeared *J. Nusbaum's* description of the pleuropodia of *Meloe* ['89]. *Nusbaum* regards these organs as glandular, but terminates his paper in a confusion of ideas as evinced by the following remark: "Die druesige Natur der Bauchanhænge bei den genannten Insekten [*Meloe, Stenobothrus*] [die ohne Zweifel auch bei anderen gefunden werden wird] spricht dafuer, dass wir es hier wahrscheinlich mit rudimentaeren Organen, die nicht bloss zur gewoehnlichen Gangfunktion bei den Insektenvorfahren, sondern vielleicht auch noch zur Atmungsfunktion dienten, zu thun haben."

I fail to comprehend how the glandular nature of the pleuropodia can in any way suggest that they may have functioned simultaneously as ambulatory and respiratory organs.

The following are my reasons for assigning a glandular function to the pleuropodia:

1. The entire ectoderm of Arthropods, excepting its nervous derivatives, is essentially a glandular layer, one of its prime functions being the secretion of the chitinous armour so characteristic of these animals. This function is retained by the ectoderm cells, even when they are pushed into the body as in the case of the tracheae, tentorium, œsophagus and rectum. Looking at the compound Arthropod eye from *Watase's* standpoint ['89], as a cluster of ectodermic invaginations we have a case where ectodermic cells still retain their chitin-secreting habits though pushed below the surface of the general integument and covered by superjacent cells.

2. The pleuropodial cells closely resemble other simple ductless glands in insects, such as the wax-glands of the Aphididæ and the stinging glands of some Lepidopterous larvæ. In the embryo and young larvæ of the Bombycid *Hyperchiria io*, I have observed the formation of the huge branching spines, which arranged in several parallel rows, repel the insects enemies with their stinging secretion. The immensely enlarged ectoderm cells which secrete the poison in the lacunæ of the spines, have very glandular cytoplasm and large nuclei, thus resembling the pleuropodial cells of *Blatta*.

3. The pleuropodial cells in several insect embryos produce a secretion, the character of which differs considerably in different forms.

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* This number of the Naturalist did not appear till Nov. 18th, 1889.

4. In some insects at least [*Blatta, Periplaneta, Xiphidium, Stenobothrus*] the chitinous cuticle does not cover the pleuropodia, even after investing the body of the embryo. On the supposition that we are dealing with ductless glandular organs, the reason for this is obvious. The secretions of cutaneous glands cannot penetrate a thick and unmodified layer of chitin, so we find gland cells covered with a cuticle the [chemical?] structure of which departs from that of ordinary chitin. This cuticle is also thinner than that secreted by the unmodified hypodermis cells of the general integument. A good example of such attenuation and modification in the molecular structure of the cuticle covering ductless cutaneous glands is furnished by the collophore of *Anurida maritima* described below. Now the first cuticle shed by the embryo in the egg must be regarded as the attenuated rudiment of what was formerly a much thicker cuticle shed by the insect in some post embryonic stage of existence. Supposing that the cuticle originally covered the pleuropodia of such an ancient insect had been more delicate than that covering the remainder of the body, it would cease to be secreted in the embryos of existing insects because reduced to such excessive tenuity. There is still another possibility which might account for our not finding a chitinous cuticle on the pleurododia: the secretion of these organs may itself be some chemical modification of the chitin, which covered the appendages before the peculiar differentiation of their cells set in.

5. The lack of any apparent innervation to the pleuropodia, though adducible as a fact against the sensory nature of the organs, is just what we should expect on the supposition that they are glandular. The difficulties encountered by histologists in tracing the innervation of glands is well known.

6. The manner in which some pleuropodia degenerate suggests what is known to take place in many glands that indicate their relation to epithelial structures by secreting their own broken-down cells. The milk glands of the mammalia and other cases will suggest themselves to the reader.

7. The structure of the pleuropodia described up to the present, though considerably diversified, is in all cases consistent with a glandular function.

Having reached the conclusion that the pleuropodia functioned as glands in ancestral insects, I have probably made the utmost use of the few facts at my disposal. The word "gland," however, is so indefinite, since the special functions of glands are so numerous, that, stopping at this point, the hypothesis is still very vague. For the sake of giving it clearer outlines, I will elaborate still further, though aware of the dangers I incur in descending to particulars.

What then was the special glandular function of the pleuropodia in primitive insects? In seeking an answer to this difficult question we are pursuing the most logical course when we muster the different classes of glands observed in air-breathing Arthropods, and select for special consideration the class that presents the greatest variation in structure and the widest distribution. On making this review we find in the first rank the odoriferous glands. These function either as means of defense or as aphrodisiacs, or probably in many species as both. The great importance of copulation and protection from enemies readily explains why the odoriferous glands should play so prepollent a role in the lives of Arthropods and even higher animals. I will give a brief though by no means exhaustive list of forms possessing odoriferous glands, for the sake of showing the wide distribution of these organs among the different groups of air-breathing Arthropods and the variety of their structure and secretions.

According to *Marx* ['86] the Pedipalp *Thelyphonus* emits a secretion which smells like acetic acid. The Myriopod *Fontaria gracilis* secretes from its series of repugnatory glands a fluid which contains free hydrocyanic acid [*Claus*, '87]. I have frequently seen our common *Julus* [*Spirobolus*] *marginatus*, when irritated emit from its repugnatory glands a brown liquid with a pungent odor not unlike bromine, though this element very probably does not enter into its chemical composition.

Among the Orthoptera numerous cases might be adduced. *Minchin* ['88] lately discovered in *Periplaneta orientalis* a new gland, which "consists of two pouch-like invaginations lying close on each side of the middle line, between the fifth and sixth terga of the dorsal surface of the abdomen." These pouches "are lined by a continuation of the chitinous cuticle, which forms within the pouches numerous stiff, branched, finely pointed hairs, beneath which, i. e., on the side towards the body cavity, are numerous glandular epithelial cells." *Minchin's* supposition that these organs are odoriforous glands has been proved to be correct by *Haase* ['89]. "Drueckt man naemlich das Abdomen einer Kuechenschabe derart, dass die Leibeshoehlenfluessigkeit nach hinten gedraengt wird, so treten zwischen dem 5 und 6. Hinterleibessegment vor den harten Rueckenplatten des letzteren zwei kleine, durch das eindringende Blut gelblich durchscheinende Saeckchen hervor und verbreiten sofort ganz intensiv den bekannten Schabengestank. Dass dieser seine Quelle in den beiden Stinkdruesen hat, wird durch vorsichtige Ausloesung der letzteren leicht nachgewiesen." Similar eversible stink-glands have been observed in the Blattid *Corydia* by *Gerstaecker* ['61] and *Haase* ['89].

An American Phasmid, *Anisomorpha buprestoides*, has well developed repugnatory glands, which have been alluded to by *Say* ('59, Vol. I, p. 84) and other writers. I quote from *Maynard* ('89) who has published the latest account: "The devil's horses, as they are called by the negroes, were in pairs, the females being evidently about to deposit their eggs. I usually found them lying quietly in a fold of the saw-palmetto, with the legs close to the body and the antennae together and pointing straight forward while the comparatively diminutive male, which is never more than a third as large as the female lay close beside his mate, always clinging to her whenever she moved and was thus carried by her. Both were very sluggish, not moving until actually touched, then the female raised herself slowly on her hind legs and straightway there emerged two streams of a vaporous fluid from the upper angle of the thorax near the neck. These streams were directed forward, but at a slight angle outwardly and upward, that is when the insect was resting on a horizontal surface. When the matter discharged first leaves the orifice from which it is expelled, it is a milky fluid, but as it is apparently as volatile as ether, it almost instantly assumes the form of vapor and is projected at least six inches. This fluid has a most peculiar pungent or peppery odor and although the moisture from it dries away very quickly from any object with which it comes in contact, the odor is retained for a long time. The fluid when thrown against the hand has no perceptible effect on the skin, but I have been told repeatedly by the negroes that the effect upon the eyes is very painful."

Odoriferous organs are well developed in the Hemiptera. Everybody is familiar with the secretions emitted from the metathoracic pear-shaped glands, the duct of which opens by means of the osteoles between the hind legs.

The Neuropteran lace-wings (*Chrysopa*) are characterized by a powerful and very unpleasant odor.

Passing to the Coleoptera, many Carabidæ, that produce from their anal glands secretions containing formic and butyric acid might be mentioned. Every collector of our native Coleoptera must have noticed the very powerful secretion produced by our common *Chlaenius sericeus* when captured. The bombardier-beetles [*Brachynus*], are well known for their habit of emitting clouds of pungent secretion accompanied by decrepitation. *Loman* ['87] has recently asserted that the gaseus secretion of the anal glands of the Paussid *Cerapterus* 4- *maculatus* contains free iodine. Among Cerambycids the European *Aromia moschata* has a powerful musky odor and the allied *Callichroma plicatum*, emits a strong honey-like smell according to the statement of my friend Mr. F. Rauterberg, who has collected numbers of these beautiful insects in Texas. The members of the genus *Meloe* exude oily drops of cantharadin from the joints of their legs when disturbed. The *Coccinellœ* have a similar habit of exuding a deep yellow liquid. The Tenebrionidæ are usually supplied with some unpleasant secretion.

Odoriferous glands occurs both in larval and imaginal Lepidoptera. *Fritz Mueller* has studied the scent glands [Duftflecken] on the wings of numerous South American Lepidoptera ('86 a — e). The forked protrusile gland of *Papilio* larvae and the pungent odor which it diffuses is well known. Its structure has been described by *Klemensiewicz* ['82]. One of our common species of *Pieris* has redolent wings. According to *Maynard* ['89] the exquisite little Bombycid *Utetheisa bella* "exudes an orange colored fluid from its thorax that has an unpleasant odor." According to Packard the larva of *Lochmœus tessella*, Pack, when disturbed sends out from each side of the body a shower, or spray of clear liquid. "The opening of the gland is in the lower anterior part of the prothoracic segment". *Poulton*

['86] has described the formic acid secretion ejected from the prothorax of *Dicranura vinula.* According to the same observer *Dicranura furcata* everts from the same region of the prothorax a gland "consisting of six diverging processes of a light green color, divided into two groups of three each." He also mentions an eversible gland in the prothorax of the larvæ of *Melitaea artemis* and *Catocala* species.

Peculiar scent organs, resembling those of the larval *Papilio* and consisting of a pair of tentaculiform processes, eversible from between the seventh and eighth ventral segments of the male imagines, have been described by *Smith* ('86) for the Bombycids *Leucarctia acrœa* and *Pyrrharctia isabella.* These processes, which are orange colored and fully half an inch long in *Leucarctia*, but whitish and somewhat shorter in *Pyrrharctia* are covered with hairs, blackish in the former and snow white in the latter species. "In both species an intense odor, somewhat like the smell of laudanum, is apparent when first the tentacles are exposed; and there is no reasonable doubt but that they are odor-glands, though exactly what purpose they serve is not so clear." *Smith* says that a Mr. Morgan has described these organs in *L. acrœa* and similar structures in *Agrotis plecta* and *Euplexia lucipara;* and that similar organs have been described for *Aletia xylina* by *Riley.*

Among the Diptera prominent cases are rare. *Coenomyia ferruginea* emits an odor which reminds me of the juice of a certain species of *Hypericum*, and which has often enabled me to detect the presence of the insect in the woods when several feet distant. The odor is retained in dried insects that have preserved for years in collections. The species of *Gastrophilus* have a sharp, disagreeable smell, powerful in some species, faint, but still perceptible in others. (*Leunis* '86, vol. II. p. 419.)

Among the Hymenoptera the formic acid secretions of the ants are well known. The catapillar-like larvæ of the species of *Cimbex,* both European and American, when irritated secrete a pungent green liquid from pores arranged along the sides of the body.

The cases cited are but a few of the many that will occur to every field entomologist. The histological structure of the glands, so different in different forms, has not been considered, as it would lead me beyond the confines of my subject. On *a priori* grounds we should expect to find that structures so useful to their possessors as the odorifferous glands are to insects, have been profoundly modified by the action of natural selection. Their wide occurrence in insects of all orders shows, moreover, that they have been in use for a great length of time. The *Archentoma* probably lived in damp places like those inhabited by the living species of *Peripatus*, *Myriopoda*, *Thysanura* and *Blattidae* and, being of a harmless nature like their modern descendants, might have made considerable use of large odoriferous glands on the pleurae.

If I am correct in my supposition that the pleuropodia functured, in the *Archentoma* as odoriferous organs, they must be regarded as much less perfect structures than their modern equivalents, such as, for instance, the anal glands of the *Carabidae* and the analogous metathoracic organs of the Hemiptera.

Of the three types of pleuropodia, which I have distinguished, the evaginate bulbiform, calyculate, and invaginate, each had its advantages and disadvantages, as a secretory organ. The evaginate bulbiform pleuropodium presents extensive secreting surface but from its prominence and necessarily delicate covering it would be readily injured. Situated on the abdomen in the median ventral line, or in line with the metathoracic legs such organs would, if prominent, be rubbed against the ground or interfere with the movements of the hind legs. This is probably why the pleuropodia move towards the pleurae and project from points outside of and near the insertion of the metathoracic legs. This position is also most advantageous for repugnatory organs.

The calyculate type, being a transition from the bulbiform to the invaginate types, has the tips of the secreting cells protected. The secretion may accumulate in the cavity of the organ and be expelled to more advantage when the animal is irritated. The projection of the organ beyond the general surface of the body, however, renders it subject to the same injuries as organs of the bulbiform evaginate type.

The advantages and disadvantages of the pleuropodia of the invaginate type are obvious. The glandular cells are efficiently projected, but in *Zaitha* and *Cicada* the secreting surface of the cells is much reduced. Were these glands hollow we should have much more efficient organs, resembling the stinkglands of *Julus*. It is probable that such hollow invaginated pleuropodia will yet be discovered in some insect embryos. (Hemiptera?)

In the best examples of modern odoriferous glands, like the anal glands of the Carabidae, where all the delicate secreting cells are protected by being pushed into the body cavity, their being tubular or racemose greatly increases the amount of secreting surface, while the presence of a reservoir renders it easy for the insect to dispose of a great amount of its malodorous secretion at a moment's notice. Forms like the larval *Papilio* with its eversible prothoracic gland have all the advantages possessed by the bulbiform pleuropodia with none of the disadvantages, since the delicate organ can be drawn back into the integment out of the reach of injury.

The little inefficiencies exhibited by all the pleuropodia as odoriferous glands when compared with the more perfect of their modern analogues, probably explain why the latter have usurped their places. The pleuropodia would, on this supposition, furnish an excellent example of a set of organs that have gone down in the struggle for existence and have been replaced by organs of more perfect structure though of the same general function.

It is interesting in this connection to cast a glance at *Scudder's* tables illustrating the sequence and relative importance of the different orders of insects during geological time, ['86, p. 110 to 113]. *Scudder's* group of *Palaeodictyoptera* extends from the Silurian to the Trias, culminating in the Carboniferous and Permian. This group comprises the generalized precursors of the more modern Orthoptera, Hemiptera, Neuroptera, and Coleoptera. It seems not unlikely that some or all of these ancient forms may have possessed pleuropodia throughout life, and that specimens may yet be found perfect enough to show these organs in the adult. The Orthoptera, Neuroptera and Coleoptera proper appear in the Trias,* while the Hemiptera are comparatively well represented in the Lias. Now these more ancient orders, constituting the division Heterometabola (of Packard), are just the ones, as will be seen from a glance at my table, whose embryos possess pleuropodia. The Diptera, and Hymenoptera, occurring in the Lias, and the Lepidoptera, appearing in the Oolite, have to all appearances kept increasing in number and variety up to the present time. In the embryos of insects of these orders, comprising the Metabola of Packard, no pleuropodia have been observed up to date.

D. *Homologues of the Pleuropodia in the Lower Tracheata.*

A consideration of the pleuropodia of insects embryos would be incomplete without a search for their homologues among the lower Tracheata, where there are numerous forms with abdominal appendages more or less clearly developed. Organs of more or less interest in connection with the pleuropodia of insects occur in scorpions, Solifugæ, spider embryos, Symphyla and Thysanura. These cases I will consider in order.

Cholodkovsky ['89] has called attention to the "combs" of scorpions in connection with the pleuropodia of *Blatta.* These organs, according to all accounts, develop as a pair of appendages on the second abdominal segment and function throughout postembryonic life as sense organs. They cannot be regarded as the homologues of the pleuropodia, since there is no ground for maintaining a homology between the second abdominal segment of the Arthrogastera and the first abdominal segment of the Hexapoda.

Another case of a somewhat similar nature has been made known by *Croneberg* ['87] in *Galeodes araneoides.* In the just hatched embryo of this Solpugid, there is a pair of flat wing shaped appendages about 0.5 mm long on the cephalothorax intercalated between the first and second pairs of legs. Their insertions are more pleural than those of the ambulatory appendages. Like the pleuropodia of insects, they are pedunculated sacks consisting of a single layer of ectoderm cells and contain neither tracheae, muscles nor nerves. No traces of these peculiar organs are to be found in the adult *Galeodes.* It seems to me very doubtful whether these organs

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* Since the publication of Scudder's work alluded to, undoubted remains of Coleoptera have been found in the Coal Measures of Silisia.

are to be regarded as modified cephalothoracic appendages and not rather as outgrowths of the pleural wall out of line with the legs. The isolated fact, though interesting, can be of little service, till reinforced by more observations. Of course no homology can be maintained between these winglike organs and the pleuropodia of insect embryos.

In spider embryos the knob-shaped appendages on the four basal abdominal segments are very distinctly defined. They have been described by *Balfour* ['80], *Locy* ['86], *Bruce* ['87] and *Morin* ['87]. There can be no doubt, from the manner in which they arise, that these knob-shaped appendages are the serial homologues of the cephalothoracic appendages, but so vague is our knowledge of the segmental homologies between the Arachnida and Hexapoda, that it is impossible to say which of the four pairs of appendages corresponds to the pleuropodia.

Bruce ['87], maintains that in spiders "probably two abdominal appendages are invaginated to form each lung-book." According to *Morin* ['87] the first pair of knob-shaped appendages become the covers of the lungs which invaginate at their bases; the second pair disappear completely, while the third and fourth pairs form the spinnerets, the ectoderm on the summit of each of the four protuberances invaginating to form the spinning glands. Barring the question of homology, the observations on the pleuropodia of *Cicada* and *Zaitha*, given in the first part of this paper, make it easy to see how an appendage might invaginate to form a lung-book, as maintained by *Bruce*.

As soon as we reach the Symphyla and Thysanura, we no longer encounter any difficulty in settling on the true homologue of the first abdominal segment of insects.

The remarkable synthetic form, *Scolopendrella*, has twelve pairs of legs. *Ryder* ['81], *Packard* ['81] and *Haase* ['87], agree that the first three pairs are to be regarded as the homologues of the three pairs of legs of the insecta and that the three segments to which they belong, are to be regarded as the homologues of the pro-, meso-and metathoracic segments respectively. If this view be correct, and there is certainly nothing to militate against it, then we may regard the fourth postcephalic segment of *Scolopendrella* as the homologue of the first abdominal segment of insects. This being the case, the two ambulatory legs attached to this segment in the Symphyla are the homologues of the pleuropodia of embryo Hexapods.

From the *Symphyla* we pass to the *Thysanura*, a group comprising several forms of interest in connection with the pleuropodia of embryo insects. Appendages are known to occur on the basal abdominal segment in *Campodea*, *Machilis* and allied species, and in the *Collembola*. Throughout the Thysanuran group the basal abdominal segment is doubtless to be regarded as truly homologous with the first abdominal segment of the higher, or winged Hexapoda (Pterygogenea). Hence, a pair of appendages arising on this segment in the Thysanura as ectodermic evaginations, with mesodermic cores, in line with and at approximately the same time as the thoracic appendages, is to be considered as truly homologous with the pleuropodia of embryo insects.

It has long been known that species of *Campodea* bear on the first abdominal segment a pair of two-jointed appendages homostichous with the meta-thoracic legs. No such appendages appear on any of the other abdominal segments; a fact which would seem to indicate that they either still subserve some particular function or are the rudiments of once functional organs differentiated from a pair of probably ambulatory appendages. As I have been unable to obtain specimens of *Campodea* for study, and can find no record in the literature to which I have access of any observations made from sections of this pair of curious appendages, I cannot decide which of these conjectures is the more probable. Be this, however, as it may, *Campodea* is to be regarded as a form, which, so far as its appendages are concerned, remains throughout life in a stage corresponding with the Orthopteran or Coleopteran embryo just after revolution.

The second to seventh abdominal segments of *Campodea* present each a pair of small unsegmented styliform appendages. These contrast in size and shape with the pair of appendages on the basal segment. In *Japyx* the differentiated basal abdominal appendages of *Campodea* are replaced by styliform appendages, pairs of which also occur on the second to seventh segments. In *Nicoletia* and *Machilis* styliform appendages occur on the second to ninth abdominal segments. *Machilis* also presents similar processes on the coxal insertions of the meso-and metathoracic legs. The number of these style-like organs varies in different species of *Lepismina*. In *Lepisma saccharina* such appendages occur only on the eighth and ninth abdominal segments. *Oudemanus* ['89] has found them on the seventh to ninth abdominal segments of *Thermophila furnorum.*

These paired styliform processes are not regarded by *Haase* as homologous with the true abdominal appendages of the Symphyla and Myriopoda, but as homologous with the coxal spurs of the lower Tracheata. He consequently maintains that the real appendages to which they belonged have disappeared on all the abdominal segments of *Machilis* and its allies and on all except the first abdominal segment of *Campodea.* *Haase* supports this view with the following facts. In their structure the styliform appendages resemble very closely the spines and spurs so common on the body and legs of the Tracheata. They are unsegmented and unlike true appendages contain no muscular core. They correspond in structure, and in their method of insertion with the coxal spurs of Myriopods, *Scolopendrella*, Thysanura and certain *Blattœ* [notably South American Blaberidæ]. *Haase*, who seems to have given very careful attention to this subject, is very probably correct in his conclusions in regard to these styliform appendages, or "pseudozampe," as they are called by *Grassi;* still the proof cannot be regarded as complete till their early development has been studied.

Though the appendages under consideration contain no muscular tissue when fully developed, it is, of course, possible that they may have contained evaginations of the mesodermic somites during the first stages of their development. We have a case in point in the pleuropodia of insect embryos. In the younger stages, as I have shown in *Blatta*, each of the two mesodermic somites of the first abdominal segment sends a papillar process into an evaginating pleuropodium in exactly the same manner as the mesodermic somites of the thorax send processes into the legs. Subsequently, when the pleuropodia have become distinctly differentiated, the mesodermic elements, which in the thoracic appendages persist and are converted into muscles, are pushed back into the body cavity. Using *Haase's* criterion and considering only the mature appendages, we should not be justified in regarding the pleuropodia as true appendages.

The evidence in regard to the origin of the styliform appendages, which *Haase* has failed to give us, is at least in part supplied by *Oudemanns* ['87.] The Dutch investigator observed that of the three pairs of styliform processes occurring on the 7th, 8th and 9th abdominal segments in both sexes of *Thermophila furnorum*, only one pair, and that the hindmost, was to be found in the youngest specimens examined. Next in order of time appears the pair on the eighth and finally the pair on the seventh abdominal segment. This manner of making their appearance, as *Oudemanns* suggests, is strong evidence against their being true appendages. It may also be noted in this connection that the styliform appendages even in those forms that possess many pairs are longest on the posterior segments and gradually diminish in length anteriorily. This is contrary to what we expect in true appendages; for these in insect embryos usually decrease in distinctness and prominence in the opposite direction.

In the Collembola a peculiar organ, called by *Packard* the collophore, occurs in the median ventral line of the first abdominal segment. This organ is thus described by *Lubbock* ('73, p. 68):

"Underneath the anterior abdominal segment is the ventral tube, or sucker. In *Podura*, *Lipura*, and the allied genera, this organ is a simple tubercle, divided into two halves by a central slit; in other genera, as, for instance, in *Orchesella* and *Tomocerus*, the tubercle is enlarged, and becomes a tube divided at the free end into two lobes. In the *Smynthuridae* and *Papiriidae* the organ receives a still further and very remarkable development; from the end of the tube the animal can project two long, delicate tubes, provided at their extremity with numerous glands."

Lubbock makes the following remarks on the function of the collophore:

"No one, indeed, who has watched the habits of the Collembola, can doubt its function. If a *Smynthurus* is laid on its back — a position from which it has some difficulty in recovering its feet — and if, while it is in this attitude, a piece of glass is brought within its reach, the animal will endeavor to seize it with the feet, but at the same time it will project one or both of the ventral tentacles and apply it, or them, firmly to the glass, emitting at the same time a drop of fluid, which, no doubt, gives a better hold. In the parallel case of the *Poduridae*, M. l' Abbé Bourlet supposes that the ventral tube act as follows: "1° qu' il sert à ces insectes à se maintenir sur les surfaces perpendiculaires en y faisant le vide; 2° que le liquide excrété par lui sert à humecter la queue et la rainure; 3° qu' il supplée à la faiblesse des pattes dans les chutes qui suivent les sauts." I am, therefore, disposed to agree with him in so far as he denies that the adhesive power depends altogether on the viscous fluid; but, on the other hand, I cannot attach much importance to his two latter suggestions. De Geer well understood the use of this curious organ. He says: "Quand la Podure [under which name he includes the present genus *Smynthurus*] marchait contre les parois du poudrier, il lui arrivait souvent de glisser; c' était comme si les pieds lui manquaient, de façon qu' elle était sur le point de tomber; dans l' instant même, les deux filets parurent et furent lancés avec rapidité hors de leur étui, s' attachant dans le moment au verre par la matière gluante dont ils sont enduits, en sorte qu' alors la Podure se trouvait comme suspendue a ces deux filets." Nicolet gives a similar explanation of their function, and, like De Geer, attributes the adhesiveness to the glutinous matter which they secrete."

The question has presented itself to me: Is not the collophore developed from a pair of true appendages united in the median ventral line, though serially corresponding with the thoracic legs and hence truly homologous with the pleuropodia of insect embryos? Although I have been unable to give the subject the careful study which it deserves, I believe that I have unearthed a few facts calculated to answer the question in the affirmative.

The only embryological observations made up to date on the origin of the collophore are recorded in *Ryder's* brief account of the development of *Anurida maritima* ['86]. His figures [Figs. 6, 9 and 10, plate 15] show clearly that the collophore consists of a pair of true appendages applied to each other in the median ventral line, even if he had not expressly stated that "during the earlier stages the limbs, antennæ, collophore, etc., had the form of mere blunt, paired papillæ, or of blunt, clavate, tentacle-like paired outgrowths from the lateral surfaces of the ventral plate or elongated germinal area."

I can supplement this embryological evidence by a few observations on the collophore of *Anurida maritima*. This maritime species was found in great numbers clinging to the under surfaces of stones between tides at Woods Holl, Mass. Its collophore is less complicated than that of our common inland forms, and therefore better calculated to give a correct idea of the fundamental pattern underlying its structure. Specimens were killed by being placed for a minute in Carnoy's fluid heated almost to boiling and were then preserved in 80 per cent. alcohol.

The collophore is quite prominent in surface view (Fig. 16 *c.*) appearing as a heart-shaped tubercle on the middle of the ventral face of the basal abdominal segment. The lateral edges are raised to form distinct rims, crowned with a few feeble hairs. The portion included between the lateral rims is flat and of a much paler color than the remainder of the integument, which is provided with an abundance of blue pigment. A very distinct slit divides the organ into two symmetrical halves. This is all that can be seen from the surface; for further details recourse must be had to cross sections. (Fig. 15.) Here it is seen that the projection of the organ above the general surface of the segment is about equal to its diameter. The cuticle (*ct.*) is rather thick and externally very finely papillose. This unevenness of surface is continued over the lateral rims, but where the center is depressed and paler the papillose cuticle is replaced by a smooth and more delicate layer (*ct.*), which stains pink in lithium carmine. This portion of the cuticle, deeply induplicated at the median slit that divides the organ into two symmetrical halves, evidently differs considerably in its chemical structure from the unstainable papillose cuticle covering the remainder of the body. The hypodermis forming the sides of the collophore has very large flattened nuclei (*hy.*), which are almost concealed in the dense layer of pigment. Beneath it lies a mass of connective tissue (*cn*). At the inner boundary of the rim of the ventral face of the organ, where the papillose cuticle is replaced by the delicate and stainable layer, the hypodermis also undergoes a marked change. From being a rather thin, deeply pigmented layer with huge flattened nuclei it becomes a thicker layer of evenly granular, unpigmented protoplasm, smooth on its external face but raised into numerous rounded protuberances on its inner surface. (*gl.*) A spherical nucleus considerably smaller than those of the pigmented hypodermis, is lodged in each of these protuberances, which thus represent the different cells. These are not, however, separated by perceptible boundary lines: hence this modified portion of the hypodermis, and perhaps also the unmodified portion, is to be regarded as a syncytium. The whole of the hypodermis underlying the modified cuticle is peculiarly and symmetrically folded. In its center it presents a broad induplication corresponding with the narrower one of the superjacent cuticle. The cells forming this median portion are small and flat. On either side there is another rather deep infolding, to the inner angle of which a delicate muscle is attached. (*ms.*) The ventral nerve chain, indicated at *n*, runs beneath the median induplication. As may be seen from the figure, there is a wide space between the modified hypodermis and its cuticle. I have seen no traces of blood in this cavity, which in some specimens contains small masses of a granular and very deeply stainable secretion. (*s.*) Larger masses of the same substance are frequently seen clinging to the outer surface of the modified cuticle. I regard the modified hypodermis as the gland that secretes this granular substance. The cavity of the organ bounded on the outside by the hypodermis is filled with blood (*bl.*) which, when the organ is called into action, is probably forced against the glandular hypodermis, the two retractor muscles relaxing. Probably the infolding of the cuticle is pushed out simultaneously with the three infoldings of the glandular hypodermis. The great extent of surface of the hypodermis compared with that of its cuticle may indicate that during protrusion the latter is stretched and attenuated, thus allowing the secretion of the glandular cells to transude more readily.

I have made no observations on the use to which the organ is put by the living animal. The observations of *Lubbock* and *De Geer* quoted above, render it probable that *Anurida maritima* uses its collophore as a sucker wherewith to fasten itself to the surface of the stone while the water is rising and falling. It probably does not leave its place of concealment during high tide to move about on the surface of the water like some of our inland species. As its body, like that of most other species, is not readily wetted, the layer of air that would cover it when emersed might be sufficient for respiration till the returning ebb.

The collophore of *Anurida*, may be readily reduced to a pair of appendages applied to each other in the median ventral line. The median induplication of the hypodermis and the corresponding single infolding of the cuticle I take to represent all that remains of the originally wide sternal area separating the two appendages. Sections through the more complicated collophores of a few of our common Podurids have convinced me that these organs are also reducible to the simple pattern of a pair of appendages more or less closely united in the median line. I have not, however, made a sufficiently extended study of the more complicated types to be able to explain the manner in which their different parts originated. It is to be hoped that some investigator will in the near future subject these interesting organs to a rigid comparative examination, from both an anatomical and physiological standpoint. *Ryder's* observations on the embryos of *Anurida maritima*, together with the observations I have presented on the adult of the same species, render it very probable that the Collembolan collophore is to be regarded as a pair of appendages homologous with the pleuropodia of the heterometabolous insects.

It seems, moreover, not improbable that the collophore of the Collembola may have been derived directly from the pleuropodia of primitive insects. Originally a pair of protuberances, covered with a sticky, perhaps malodorous secretion, these appendages may have come to be of assistance as adhesive organs in such leaping species as had rather weak limbs and lived where they found it of advantage to alight on surfaces of different inclinations.

Milwaukee, December 20th, 1889.

While my manuscript was being copied for the printer, *E. Haase's* recent paper entitled "Die Abdominalanhänge der Insekten, mit Berücksichtigung der Myriopoden" (Morph. Jahrb. Bd XV 3. Heft. p. 331–435, 1889) came to my notice. This treatise, by far the most complete and accurate ever published on the subject, contains, besides a mass of other observations, so many interesting facts and considerations bearing on what has been set forth in my more special contribution, that I seize the opportunity to append a few paragraphs on the points of most importance in connection with the pleuropodia of insect embryos.

Haase has made a study of the pair of appendages on the first abdominal segment of *Campodea staphylinus* and finds that they are specialized to form glandular organs (p. 378–380). These two-jointed appendages do not stand off at right angles to the body but are applied to its surface. The inner face of the broadly oval distal joint, i. e., the face turned to the ventral surface of the abdomen is beset with 20–30 peculiar hairs (Haaranhänge) arranged in rows. The two outer rows are composed of longer and thicker setæ, arranged like the teeth of a comb. Each bristle is inserted on a rounded follicle (Balg) which is surrounded by a ridge. A gland-cell terminates in each follicle. This pair of appendages is regarded by *Haase* as "rudimentäre, in der Entwicklung zurückgebliebene Beine," and hence as in no sense homologous with the ventral stylets (Ventralgriffel) occurring on the 2nd to 7th abdominal segments. As evidence in favor of this view he adduces the fact that the appendages of the first abdominal segment are largest in young *Campodeæ* and that their relative size diminishes with the growth of the insect.

Haase makes a somewhat similar observation on *Iapyx gigas* and *solifugus*. In these Thysanurans no appendages are developed on the first abdominal segment, but in their stead six peculiar glands which are described as follows:

"Bei *Japyx gigas* Brauer aus Cypern, einer Art von 23-26 mm Länge, tritt an der ganzen Bauchplatte des ersten Abdominalsegmentes jederseits des schmalen, etwas eingesenkten Mittelschildes eine flache Vorwölbung der Seitentheile auf. Am Hinterrande liegen jederseits des nur 0,125 mm breiten mittelsten Stückes, das eine einfache dünne Duplikatur der Ventralhaut darstellt, drei scharfbegrenzte, von einer bindegewebigen Membran umschlossene Drüsenzellmassen, welche selbst in zurückgezogenem Zustande den Plattenrand noch überragen und von einer schmalen Ringfalte eingeschlossen sind. Die äusserste Drüsenmasse ist bei 0,25 mm Länge 0,135 mm hoch und an den Vorderecken abgerundet. Die mittlere bildet einen eher abgerundet rechteckigen Körper von 0,13 mm Länge und 0,13 mm Höhe; die innerste ist flach und quer gestreckt, 0.26 mm lang und nur 0,09 mm hoch. Die beiden äusseren Drüsenmassen sind an ihrer freien Hinterfläche sehr dicht, die innerste spärlicher mit starren, spitzen, gelben Börstchen besetzt, die bis 0,03 mm lang werden und deren an der mittleren Masse gegen 100, an der äussersten über 200 vorkommen. Die Drüsenzellen sind trübe durchsheinend, von gelblicher Farbe."

"Der Bau der Drüsenmassen am ersten Hinterleibsringe von *J. gigas* wurde an Längschnitten untersucht. Die auf der Cuticula stehenden Härchen sind gelblich und bis zur Spitze von einem weiten Kanal durchzogen, der scheinbar direkt in den langen Hals einer einzelligen Drüsenzelle übergeht. Die Ausführgänge sind in der Mitte oft stark aufgeblasen, während sie sich am Ende wieder bis zu 0,001 mm Durchmesser verschmälern.

Aehnlich lässt sich auch bei *J. solifugus* der Uebergang des die hohlen kurzen Haarstacheln durchziehenden Kanals in den dünnen 0,02—0,03 mm langen Ausführungsgang einzelliger rundlicher Hautdrüsen von 0,005—0,008 mm Durchmesser erkennen."

These observations on *Campodea* and *Japyx* are of considerable interest in connection with the hypothesis advanced in the concluding paragraphs of my paper. Notwithstanding the glandular portion of the first abdominal segment in *Japyx* is broken into six clearly defined masses, it may still be true that originally the three glands on either side of the median sternal line formed only one mass. The pair of glands which might thus have given rise to the six separate masses mav be traced back through structures like the pleuropodia of *Cicada* to a pair of true glandular appendages like those on the first abdominal segment of *Campodea*. *Haase's* Fig. 17, Plate XV, representing a section through the glandular mass in *Japyx*, calls to mind the pleuropodium of *Zaitha*.

Haase also gives a very interesting account of the eversible sacks, which have long been known to occur in pairs on the ventral faces of the abdominal segments in many Thysanura. He has subjected both literature and insects to a painstaking examination, with results that I here very briefly summarize: In the Myriopod *Lysiopetalum* (two species) pairs of eversible sacks occur on the coxæ of the 3rd–16th pairs of legs; in *Polyzonium germanicum* and a Moluccan *Siphonophora* there is a pair of these sacks on nearly every segment caudad from the third. *Scolopendrella* has 10 pairs of eversible sacks, a pair on each segment from the 3d to the 12th. In *Campodea* they are present on the 2nd to 7th abdominal segments; in *Japyx* on the 2nd abdominal segment. In *Machilis maritima* and *M. polypoda* pairs of eversible sacks occur on the 1st to 7th abdominal segments; one large pair on the first and two smaller pairs on each segment from the 2nd to the 5th; the 6th and 7th segments are each provided with but a single pair of small sacks. Experimental evidence is adduced to prove that the eversion of these sacks is a voluntary act on the part of the insect, brought about by blood pressure, and that when everted these organs subserve a respiratory function. To distinguish them from tracheal and vascular gills *Haase* designates them "*Blutkiemen.*"

The study of these peculiar organs naturally leads to a consideration of the Collembolan collophore, to which *Haase* also ascribes a respiratory function. Since he has not yet completed his study of this organ, his remarks are meagre, and, I believe, open to some objection. Thus, in disregard of *Ryder's* observation on the embryo *Anurida*, he supposes the bifurcate, protrusible and glandular portion of the collophore to be derived from a pair of eversible sacks apposed in the median ventral line. On page 373 he remarks: "Wie zuerst J. Wood-Mason hervorhob, ist die Entstehung des Ventraltubus der Collembola auf die Verschmelzung eines Abdominalsackpaares, wie sie bei Thysanuren auftreten, zurückzuführen, und in Uebereinstimmung damit ist auch bei den weniger rückgebildeten Formen die Bilateralität der Endsäckchen noch deutlicher ausgeprägt." He is careful not to maintain an homology between the pleuropodia of insect embryos and the eversible sacks of the Thysanura, though he agrees with *Graber* in ascribing to the pleuropodia a respiratory function. The wish to homologize the collophore with a pair of eversible sacks seems to have prevented *Haase* from seeing the at least equally probable homology between the collophore and the pair of appendages on the first abdominal segment of *Campodea* and between these last appendages and the pleuropodia of insect embryos — an homology which I could only surmise, but which *Haase's* own observations now render very probable.

Though *Haase* regards both the Ventralsäckchen and the collophore as respiratory organs, he nevertheless believes them to have arisen from what were originally glandular structures. This is very clearly expressed in the following paragraphs, quoted because they make to a certain extent for my theoretical conclusions in regard to the pleuropodia.

"In der That ist es wahrscheinlich, dass die Ventralsäcke der Symphylen, Chilognathen und Thysanuren auf weit verbreitete drüsige Bildungen zurückzuführen sind. Um nur die Antennaten zu berühren, so liegen die verschiedenen Organe alle nahe der Beinwurzel an der Unterseite order an entsprechenden Stellen der Bauchplatten, auch scheint ihr Bau auf *ein* Schema zurückführbar, auf eine Einstülpung der Chitinhaut, die über drüsigem Epithel liegt und entweder als Coxal-order Cruraldrüse dem Beine fest eingefügt ist order als Ventralsäckchen willkürlich durch Blutfüllung vorgestülpt und durch Muskeln zurückgezogen werden kann." After mentioning the coxal and crural glands of *Peripatus* and the *Myriopoda*, and describing the peculiar coxal secretion of Lithobiids, *Haase* continues: "Es ist nun sehr wahrscheinlich, dass diese (the eversible sacks) als Derivate von Drüsen aufzufassen sind, welche ihre secernirende Funktion mit der respiratorischen vertauschten, wie dies ähnlich von der Umwandlung von Hautdrüsen zu Tracheen angenommen wird. Auf die ursprünglich drüsige Natur der Hüftsäckchen deuten wohl noch die Riesenkerne in der Matrix derselben bei *Scolopendrella* und *Campodea*.

"Die rein drüsige Natur homologer Gebilde tritt uns, vielleicht sekundär unter den Thysanuren bei *Japyx* entgegen, wo bei *J. gigas* und *J. solifugus* kompakte Drüsenzellhaufen auftreten, deren Sekret sich in feine Hohlhaare ergiesst. Dass ähnliche Organe, wie die von *Japyx* auch die Vorläufer der respiratorischen Säckchen sein konnten, ergiebt sich schon daraus, dass letztere bei *J. gigas* an derselben Stelle, wenn auch in unvollkommener Form, am zweiten Abdominalsegment auftreten.

Die ursprünglich drüsige Natur der Bauchsäcke von *Machilis* scheint, wie durch die eigenartige Matrixlage, so auch durch die langen gereihten Haare an der Dorsalseite der eingestülpten Säckchen bezeichnet zu sein, die mit verkümmerten einzelligen Hautdrüsen in Verbindung stehen."

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EXPLANATIONS OF THE PLATES.

PLATE 1.

Fig. 1. Lateral view of a *Blatta* embryo 16 days old [during revolution] *a*, amnion; *sr*, serosa; *lb*, labrum; *md*, mandible; mx^1, first maxilla; mx^2, second maxilla; *at*, antenna; p^1, p^2, p^3, thoracic limbs; *ap*, pleuropodium, or appendage of the first abdominal segment.

Fig. 2. Longitudinal section through the metathoracic and first three abdominal appendages of a *Blatta* embryo 12 days old; p^3, metathoracic leg; *ap*, ap^2, ap^3, first, second and third abdominal appendages; *ms*, mesodermic somite; *ecd*, ectoderm.

Fig. 3. Longitudinal section through the pleuropodium of a *Blatta* embryo 14 days old; *ecd*, ectoderm; *ms*, mesoderm; *v*, vacuole.

Fig. 4. Three cells from the same series of sections as Fig. 3. Zeiss hom. immers., $\frac{1}{12}$ oc. II. *v*, vacuole; *nc*, plastine nucleolus.

Fig. 5. Five nuclei from a longitudinal section of the pleuropodium of a *Blatta* embryo 20 days old; drawn with focus on the equatorial plane. Magnification same as in Fig. 4.

Fig. 6. Longitudinal section of a pleuropodium of a *Blatta* embryo 19 days old. *pd*, peduncle; *cv*, cavity; *cn*, constriction; *v*, series of vacuoles.

Fig. 7. Longitudinal section from a pleuropodium of a *Blatta* embryo 20 days old. Reference letters same as in Fig. 6.

Fig. 8. Longitudinal section of a pleuropodium from a *Blatta* embryo about 25 days old. *n*, nuclei; *pl*, protoplasm.

Fig. 9. Section through a pleuropodium of a *Blatta* embryo 26 days old. *n*, nuclei; *pl*, protoplasm.

PLATE 2.

Fig. 10. Longitudinal section through a pleuropodium of an embryo *Periplaneta orientalis*, in a late stage, after the closure of the body walls in the median dorsal line and the secretion of the first cuticle. *ecd*, ectoderm; *ms*, mesoderm [connective tissue]; *pl*, protoplasm issuing from the distal end of the organ; *t*, tips of pleuropodial cells; *v*, vacuole; *x*, two pleuropodial cells about to pass through the peduncle into the body cavity of the embryo.

Fig. 11. Longitudinal sections through a pleuropodium of an embryo *Mantis carolina* before revolution; *ecd*, ectoderm; *ms*, mesoderm; *x*, point where the ectoderm is comparatively thin; *p*, one of the thoracic appendages; *ap*, pleuropodium.

Fig. 12. Cross section through one of the pleuropodia of an embryo *Xiphidium ensiferum* during revolution; *sr*, serosa; *as*, amniotic secretion; *ct*, chitinous cuticle; *ap*, pleuropodium; *cv*, cavity; *p*, one of the thoracic appendages; *ecd*, ectoderm; *ms*, mesoderm.

Fig. 13. Section through the base of one of the pleuropodia of *Xiphidium ensiferum* just before hatching; *ap*, pleuropodium; *pd*, peduncle, inserted in a pit of the hypodermis *ecd*, which has secreted its second cuticle, *ct*; *s*, granular secretion.

Fig. 14. Cross section through the same pleuropodium; *s*, granular secretion; *cv*, cavity.

Fig. 15. Cross section through the coilophore of *Anurida maritima* [adult]; *ct*, cuticle; *hy*, large nucleus of the hypodermis; *pg*, hypodermic pigment; *ct*, delicate cuticle covering the glandular part of the organ; *s*, granular secretion; *gl*, gland cells; *ms*, retractor muscles of the glandular hypodermis; *cn*, connective tissue; *st*, sternum; *bl*, blood.

Fig. 16. Surface view of the collophoral (first abdominal) segment of the adult *Anurida maritima.* p^3, metathoracic legs; *ab*, first abdominal segment; *c*, collophore.

PLATE 3.

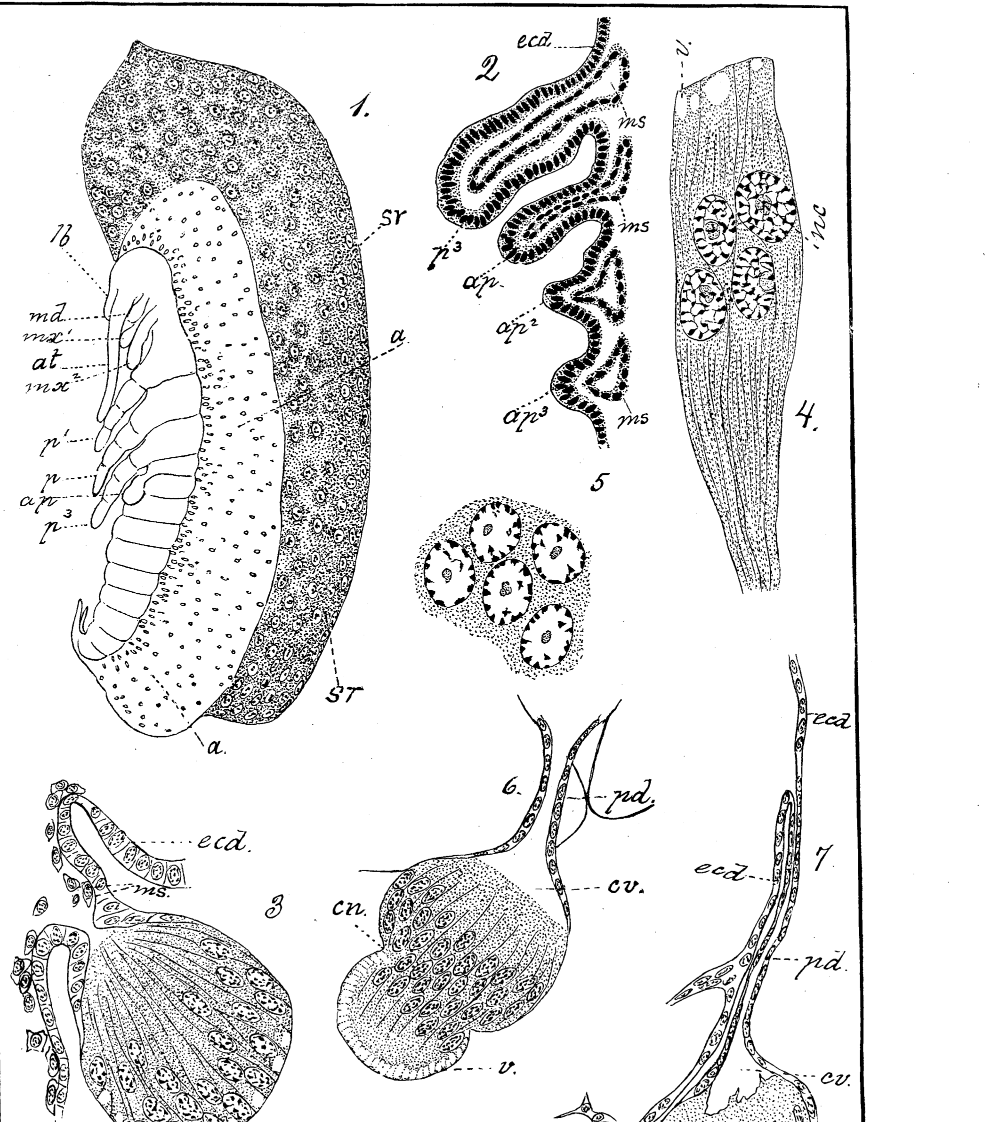
Fig. 17. Half of a transverse section through the first abdominal segment of the embryo *Zaitha fluminea* during revolution. *ap*, pleuropodium; *s*, penicillate secretion; *ecd*, ectoderm; *ent*, entoderm; *vt*, yolk; *vp*, vitellophag; *cn*, connective tissue; *ms*, muscle; *ad*, corpus adiposum; *cb*, cardioblast; *gl*, ganglion of the first abdominal segment.

Fig. 18. Three cells from a pleuropodium of *Zaitha fluminea* enlarged. *x*, granular and widened inner ends of cells; *h*, hyaline and attenuated outer ends of cells; *s*, threads of secretion. Zeiss. homog. immers. $\frac{1}{18}$ Oc. II.

Fig. 19. Longitudinal section of a pleuropodium of the embryo *Cicada septemdecim* during revolution. *ap*, pleuropodium; *s*, secretion;

as, amniotic secretion; *p*, one of the thoracic appendages; *ch*, chorion; *ecd*, ectoderm; *ms*, mesoderm; *ct*, connective tissue; *vt*, yolk.

Fig. 20. Portion of a transverse section through the ventral plate of a *Cicada* embryo before revolution. *a*, amnion; *ecd*, ectoderm; *ap*, pleuropodium forming as an apple-shaped thickening of the ectoderm; *gl*, ganglion of the first abdominal segment; *ms*, mesodermic tissue.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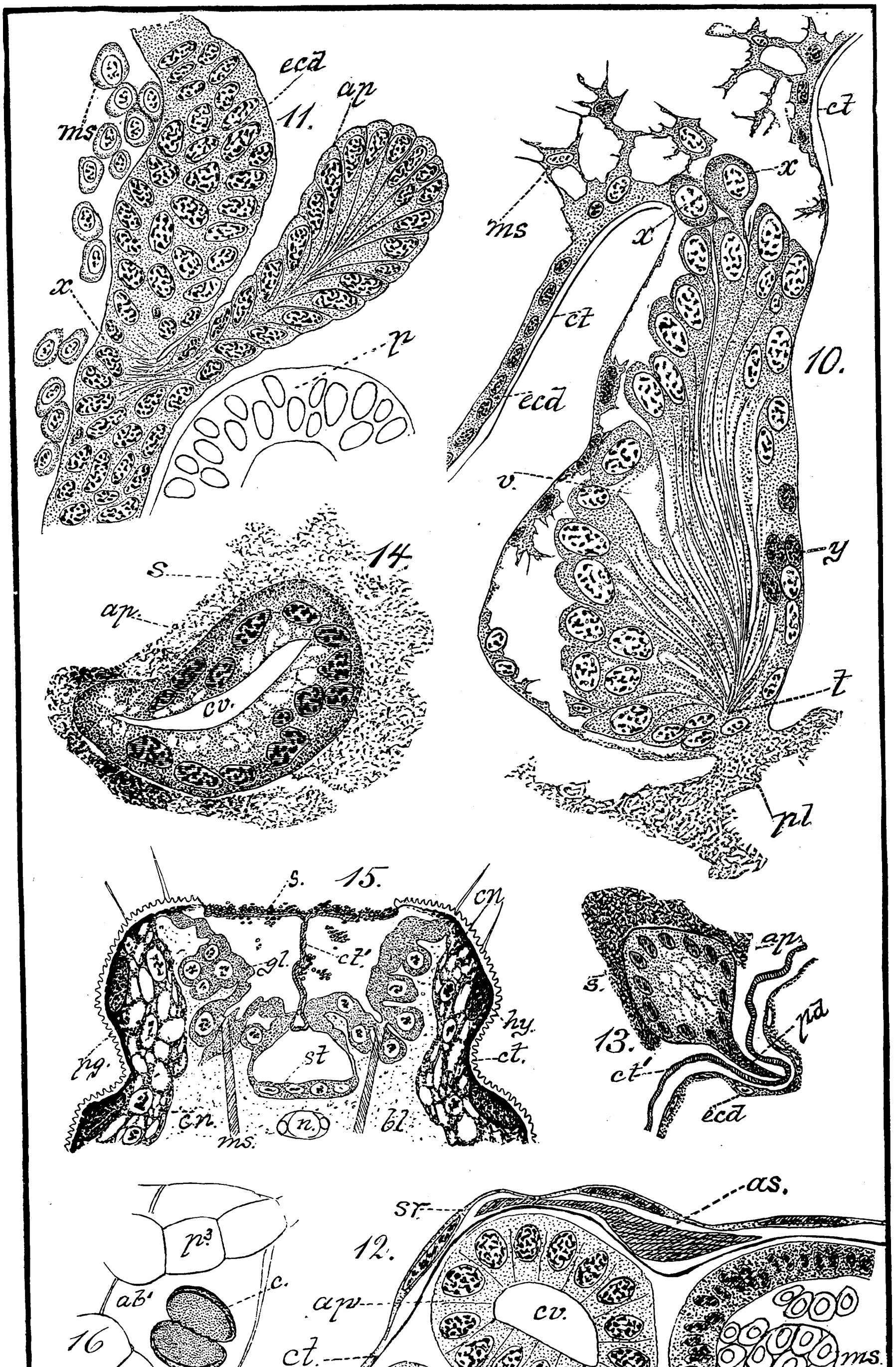
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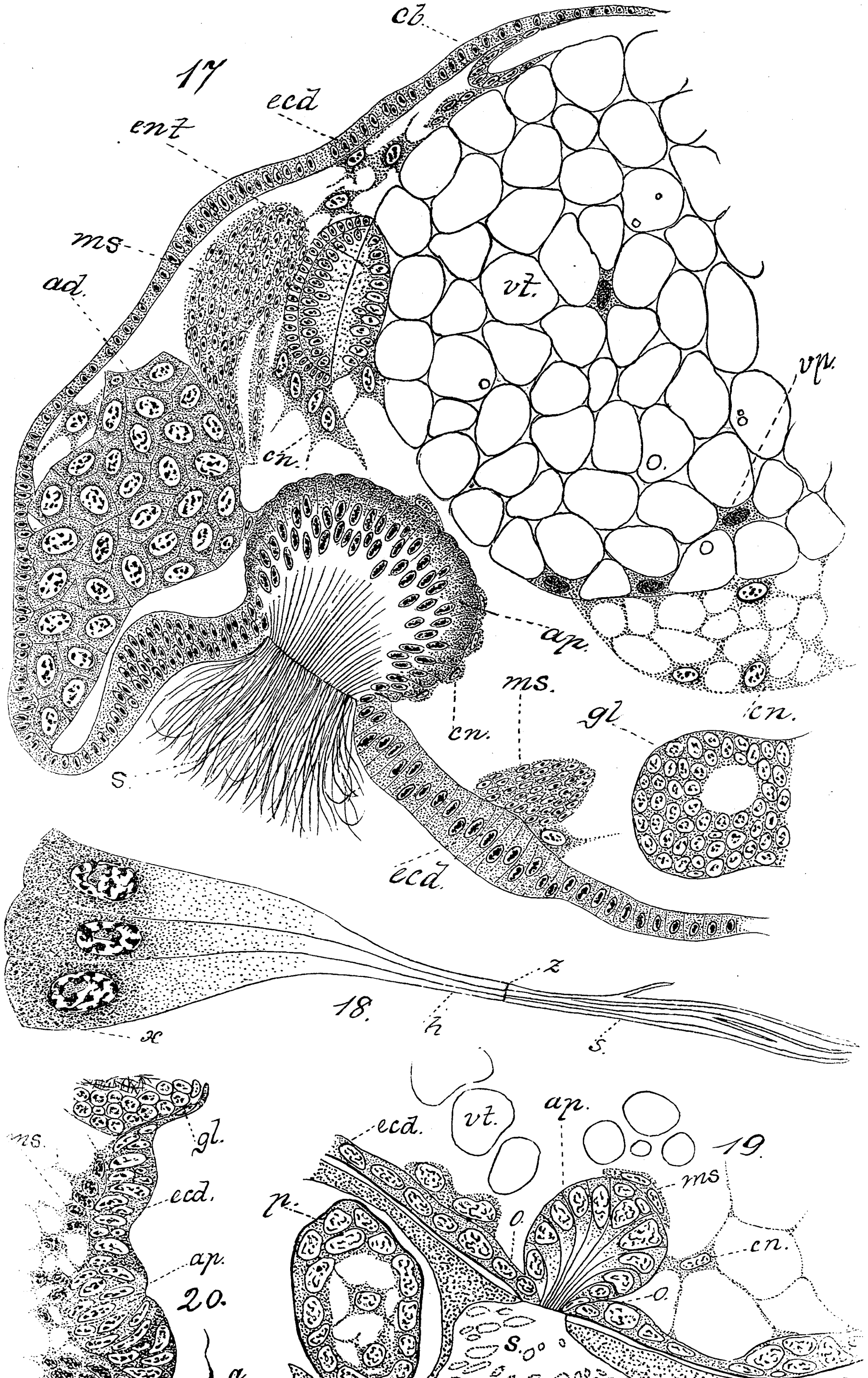
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SOME NEW THEORIES OF THE GREEK KA-PERFECT.

BY CHAS. E. BENNETT.

In spite of all that comparative grammar has done to throw light upon the morphology of the different Indo-European languages, there yet remain in the individual languages a goodly number of formations without correspondence in any other language. As examples of such isolated formations may be cited the Greek passive aorists in -ην and -ϑην, the so-called -*n*- or weak declension of the Germanic languages, and the gerundive of the Latin.

With regard to these and similar formations two theories might at first suggest themselves:

First, that we have to do with primitive Indo-European formations, the traces of which have disappeared in the other languages and are preserved in one alone, or

Secondly, that the formation does not go back to the Indo-European *Ursprache*, but is a new creation of the particular language in which it is found.

As a matter of fact we at once discard the theory that any formation of the nature in question existed as such in the Indo-European *Ursprache*. Unless we have the combined testimony of at least two groups of languages as to the primitive character of a formation we shall not be justified in attributing it to the *Ursprache*. We must rather view such a formation as due to the specific agency of the particular language in which it is found, as produced by way of analogy or association with other formations of the same language, by the use of inflectional material already at hand.

It is in this way that we explain the origin of the weak or -*n*- declension in the Germanic group. The -*n*- declension arose simply from a wider extension and more frequent application of endings which were originally peculiar to -*n*-stems, such as Latin *nomen*, Greek *δαίμων, etc.* So in Greek the so-called 1st and 2nd aorists passive in -ην and -ϑην were originally nothing more than intransitive 2nd aorists active of the -μι form, *i. e.*, constructed after the analogy of forms like *ἔβλην ἔστην, etc.* The formation in -ην was the earlier, as in *ἐπλάκην, ἐστάλην, ἐφάνην, etc.*, while the so-called first aorists in -ϑην are formed after the analogy of those in -ην, under the influence of such presents as *σχέϑω, πλήϑω, φϑίϑω, βιβάσϑω, νεμέϑω, ἄχϑομαι, νήϑω, μινύϑω, πρήϑω, κνήϑω, etc.*

The above are cited simply as examples to illustrate the methods by which we may expect to explain similar formations peculiar to a single language, and which therefore cannot be referred to the *Ursprache* for their origin. Such a formation is the Greek perfect in -ϰα. No other Indo-European language presents any trace of it, and we therefore assume that we have to deal with a formation which has developed itself on Greek ground by way of association or analogy with some other inflectional form of the Greek language.

There have lately appeared several new theories in explanation of the -ϰα-perfect. The two most important of these have emanated from the school of the so-called "*Junggrammatiker*," and have been propounded by the heads of the school, one by Prof. Brugmann of Leipsic, the other by Prof. Osthoff of Heidelberg. A third is that of Felix Hartmann.

Before taking up the consideration of these theories, let us state more precisely the problem to be solved. The oldest formation of the Greek perfect, was unquestionably by the suffix -α, appended to the strong form of the root, with the reduplication prefixed, *e. g.*,

root λειπ-, perf. λέ-λοιπ-α.
root πειϑ-, perf. πέ-ποιϑ-α.
root φευγ-, perf. πέ-φευγ-α, earlier *πέ-φουγ-α.

The Sanskrit formed its perfect in the same way, and there can be no doubt that the formation goes back to the *Ursprache*, for its origin. But by the side of this Greek perfect in -α we find in the oldest monuments of the language also a considerable number of perfects in -ϰα. As time goes on this number increases, and in the Attic of the 4th century B. C. the -ϰα perfect is the regular formation for all verbs except stems in labial and palatal mutes and a few others, which have retained the old -α- formation.

The problem before us is to explain this -ϰα; why we have -ϰα instead of -α.

BRUGMANN'S THEORY.

Brugmann's theory appeared first in Vol. XXV. of *Kuhn's Zeitschrift für Vergleichende Sprachforschung*, p. 212 ff., 1879.

As he omits some of the earlier theories we may mention them here.

An examination of the perfects used by Homer discloses the fact that but an extremely small number of -ϰα- forms occurs. While perfects in -α, as πέποιϑα, εἴληχα, εἴληρα, ϰέϰραγα, *etc.*, are very numerous, the -ϰα-perfects found in the Iliad and Odyssey together number only twenty. As examples may be mentioned, βέβηϰα, βέβληϰα, δέδυϰα, ἕστηϰα, πέφυϰα, τέϑηϰα, τέτληϰα. All the Homeric -ϰα-perfects, moreover, are from vowel stems. There are no Homeric -ϰα-perfects from consonant stems, such as the later Attic πέπειϰα, ἔσταλϰα ἔφϑαρϰα, πέφαγϰα.

This circumstance led Thiersch and subsequently Ahrens to explain the ϰ as inserted between two vowels for the purpose of avoiding hiatus, so that according to this theory βέβηϰα would be explained as arising from *βέβηα, by the insertion of ϰ; so ἕστηϰα from an imaginary *ἕστηα. As a ground for this explanation Thiersch and Ahrens cited *οὐκέτι* and *μηκέτι*. But the *κ* here belonged originally to the *οὐκ* in all probability, so that *οὐκέτι* is for *οὐκ-έτι* (not for an earlier **οὐ-έτι*), while *μηκέτι* is formed after the analogy of *οὐκέτι*.

It is scarcely necessary to add that a theory involving such an extraordinary phonetic phenomenon as the bodily insertion of *κ*, a change not only not elsewhere exemplified in Greek, but also without analogy in other languages, is unworthy of further consideration to-day, when the inviolability of phonetic laws is so insisted upon by even the less rigid investigators.

Curtius, in his earlier work, the *Tempora und Modi,* followed Thiersch and Ahrens, but in his *Verbum der Griechischen Sprache,* he propounds the following explanation of the *-κα-* perfect. He designates the *-κα* as a "*stammbildendes Element.*" He further assumes that nominal stems were first formed with this suffix; and from these nominal stems verb-stems, just as the verb-stems in *-να-*, *-νυ-*, *-νο-*, *-ανο-*, *-το-*, *-σκο-*, are, by Curtius, in their origin, assumed to be nominal stems. Curtius further says, "Assuming that there was a nominal stem **βᾰ-κᾰ* (Ion. **βη-κᾰ*) then from this we might have a reduplicated *βέ-βᾰ-κα* (Ion. *βέ-βη-κα*), and such reduplicated stems might, in the period when the verbal forms were still undetermined, establish themselves here and there in the perfect by the side of the shorter forms in *-α*."

To this theory of Curtius Brugmann presents the following objections:

1. Where are these nominal stems in *-κα*? The language does not seem to have had them. We should expect them to exist in some abundance; but we find only a very few. We may cite *ϑήκη* and *σωκός*; but from *ϑήκη* we could hardly directly explain the form *τέ-ϑεικα* as the vocalism of the two words is different, one having *η* the other *ει*. Nor can we satisfactorily explain the aorist *ἔϑηκα* from *ϑήκη*. For *ϑήκη* means 'chest, vessel,' and the testimony of the Sanskrit *dhâ-kâ*, which has the same meaning, seems to indicate that in the *Ursprache* the word had this specialized sense of the root *dhê-*. It is difficult to comprehend how a denominative aorist or perfect in the sense of 'put' should be formed from a noun meaning 'holder.'

2. Curtius speaks of a form *βέβηκα* establishing itself by the side of a form **βέβηα* at a time when the verbal inflections were still undetermined. Brugmann with propriety inquires when Curtius conceived this to have been. Was it subsequent to the period of the *Ursprache?* If so, he should remember that the verbal inflections were then no longer undetermined. The substantial unity of the verbal inflection of the separate languages shows this. Or does Curtius mean the period of the *Ursprache?* If so he should consider that we can not pretend to explain a formation which has confessedly developed upon specific Greek ground, by referring to the *Ursprache*, or any conditions which may have prevailed in it.

To these two leading objections of Brugmann might be added another, *viz.:* Is it conceivable that denominative verbs in simple -*ω* should be formed from stems in -*ᾱ* (Ion., Attic -*η*) *e. g.*, a **βήκω* from **βήκη*? Could we expect anything else from **βήκη* than **βηκάω* or **βηκέω*? Would not the overwhelming abundance of denominatives like *τιμάω*, *ἀράομαι*, *φιλέω*, *etc.*, be a sufficient assurance that, even admitting the existence of *βήκη*, we should never have had a form **βήκω* from it, from which to produce a perfect *βέ- βηκ-α*?

In view of the objections which Curtius's theory raises against itself Brugmann thinks we must try in another way to solve the problem of the -*κα*-perfect. From an examination of verbal formations in -*κ*- Brugmann finds six which are pre-Homeric. These are:

ὀλέκω
δώκοι (on the Idalian Bronze Tablet, line 16.)
δειδίσσομαι (for *δειδίκιομαι*.)
The three aorists *ἔδωκα*, *ἔϑηκα*, *ἧκα*.

To all of these forms correspond perfects in -*κα*, which likewise seem to belong to the primitive stages of the language. These are *ὀλώλεκα*, *δέδωκα*, *δείδοικα* (*i. e.*, **δέδϜοικα*), *τέϑηκα* (*τέϑεικα*), *εἷκα*.

Brugmann subjects each of these verbs to a careful examination with reference to determining whether their -*κ*- not only is pre-Homeric but possibly even dates from the *Ursprache*. He arrives at a negative conclusion with reference to the forms *ἧκα*, *ἔϑηκα*, *δειδίσσομαι*, with their corresponding perfects *εἷκα*, *τέϑηκα* (*τέϑεικα*), *δείδοικα*.)

With reference to *ὀλέκω* and its perfect *ὀλώλεκα*, he finds it impossible to reach a decision, owing to its obscure etymology. *ἔδωκα* with its perfect *δέδωκα* and its present optative *δώκοι* is the only one of the -*κ*-formations which Brugmann concedes goes back to the *Ursprache* for its origin.

This form *δέδωκα* Brugmann derives from the root *δωκ*- and identifies with the Sanscrit *da-dâç-a*. The correspondence in form between the two is exact. The signification also of the Sanskrit *da-dâç-a* is the same as that of *δέδωκα*. For the Sanskrit root *dâç*- means 'give, vouchsafe, offer,' just as does the root *dâ*- = Greek *δω*-.

The so-called aorist active *ἔδωκα* Brugmann also derives from this same root *δωκ*- (Sanskrit *dâç*-). This *ἔδωκα* is for an original **ἔδωκ-m*, *m* representing the vocalic nasal or "nasalis sonans," which when unaccented regularly develops in Greek as *α*; just as the Rhenish Germans say *gegange* for *ge-gang-n* (*i. e.*, *gegangen*), *geritte* for *gerittn* (*i. e.*, *geritten*), *obe* for *obm* (*i. e.*, *oben*). Other examples in Greek of the development of the vocalic nasal or "nasalis sonans" are *ἔλυσα* (for **ἔλυσm*), *γεγράφαται* *τετράφαται* (for **γεγράφ-nται*, *etc.*; *cf.* *βε-βούλευ-νται*).

According to the above view of the forms *ἔδωκα* and *δέδωκα* we have, in the different systems of the Greek verb *δίδωμι*, to deal with two roots, one root *δω*- corresponding to the Skrt. *dâ*- and another *δωκ*- corresponding to Skrt. *dâc*- Both roots are nearly identical in meaning and hence have become united in one verb; just as frequently the same thing occurs where the different roots are clearly distinct, *e. g.*,

ὁράω, ὄψομαι, εἶδον
φέρω, οἴσω, ἤνεγκον.

δέδωκα therefore is δέ-δωκ-α, *i. e.*, a regularly formed perfect from the root δωκ- with the ending -α, the regular ending of the perfect both in Greek and Sanskrit, as seen in πέποιϑα, λέλοιπα, πέφευγα and numerous other similar forms; and it is from this one form that Brugmann conceives the entire category of -κα- perfects to have arisen, and in the following way. After ἔδωκα and δέδωκα had become part and parcel of the verbal system of δί-δω-μι they were mentally referred to the root δω- also, and the ending -κα was felt as a tense-suffix.

As soon as it was felt as such it began to be employed in the formation of other perfects with long vowel roots, *e. g.*, ἕστηκα (στη-), βέβηκα (βη-), πέφῡκα (φῡ-).

Brugmann thinks he discovers a particular reason why the -κα- formation was so readily adopted by the long vowel stems. The original inflection of the singular of the perfect indicative of the root δω-, for example, must have been:

* δέ- δω- α
* δέ- δω- ς (-ϑα)
* δέ- δω- ε

By contraction this must have early given:

* δέδω
* δέδως
* δέδω

These forms were felt to lack the distinctive perfect character and were likewise identical in the 1st and 3rd singular. Hence it was that the language readily availed itself of such formations as ἕστηκα, βέβηκα, πέφῡκα. It is at about this stage in the history of the perfect that the Homeric poems belong. The -κα-perfects in Homer are almost exclusively from long vowel roots; but short vowel roots are also just beginning to adopt the -κα- formation, *e. g.*, *βεβίηκα, δεδείπνηκα, etc.* Still later and subsequent to Homer are the formations from consonant stems, such as ἔσταλκα, ἔφϑαρκα, πέπεικα, ἤγγελκα, τεϑαύμακα.

The theory that one form like δέδωκα should have been the type that has called hundreds of others into existence seems at first, perhaps, too remarkable to be lightly credited; yet similar phenomena are well attested for other languages. Thus in Old Bulgarian the first singular of the verb in the present indicative ended almost always in *a* = original Indogermanic ō. Only four verbs had the ending *-mi, viz: jesmi, věmi, dami, jami.* Yet these four verbs have been the type from which all verbs in the modern Slovenian and Servian languages form their 1st person singular present indicative in *-m*. So we have hundreds of forms from four alone. So also in German we have in the nominal inflections the frequent plural ending -*er* producing Umlaut of the root syllable, *e. g.*, *Thal*, *Thäler; Buch*, *Bücher; Grab*, *Gräber; Irrthum*, *Irrthümer; Kalb*, *Kälber*, and very many others. All of these are modern except *Kalb*, *Kälber*, which must be considered as having furnished the starting point for the whole category. The plural *Kälber* therefore in the number of forms it has called into existence would furnish an exact parallel to *δέδωκα.*

An interesting and instructive illustration is furnished also by the Italian. The Latin *steti*, *stiti* became in Italian *stetti.* This form was felt as consisting of *st*- as root and -*etti* as the ending. So by the analogy *sto*, *stare*, *stetti*, we got in Italian from *do*, *dare*, the perfect *detti* instead of *diedi* (Latin *dedi*). The ending -*etti* was then applied to other verbs, such as *vendetti*, *fremetti*, *credetti*, *dovetti* and many others. I have not been able to determine the exact extent of the application of this ending, from lack of the requisite books of reference, but am convinced that it is quite extensive.

The example is at all events a striking one of how even one single form can furnish the model after which innumerable others may be constructed. *Stetti*, therefore, would furnish a complete analogy of what we have claimed for *δέδωκα*. It is historically certain for *stetti*; it is therefore very possible for *δέδωκα*.

The objection then to one form's being the starting point for many would seem to be met by the above considerations.

Hermann von der Pfordten in his *Geschichte des griechischen Perfects* calls attention further to the fact that the other perfects from stems in -*κ*- as:

δέδορκ-α	(root *δερκ*-)
μέ-μυκ-α	(root *μυκ*-)
τέ-τηκ-α	(root *τηκ*-)
μεμηκ-ώς	(root *μηκ*-)
πέ-φρικ-α	(root *φρικ*-)
ἔοικ-α	(root *Fεικ*-)

may have contributed to the illusion that -*κα* was a tense suffix and so have assisted in its application to other roots.

In fact von der Pfordten thinks that even the so-called -*κα*- aorists *ἔδωκα*, *ἔθηκα*, *ἧκα* may have contributed their share in the same direction, especially when one considers the great frequency of these words (some 500 times) in the Homeric poems, the very stage of the language at which we find the -*κα*- formation just beginning to assume greater proportions.

Brugmann's theory then may be summed up in the following words:

There was in Greek an early confusion of two roots of the same meaning, *δω*- and *δωκ*-, *δω*- being used for the present and future, *δωκ*- for the aorist and perfect. By reason of this confusion the ending of *δέδωκα* was felt as -*κα* instead of -*α*, as it really was; and being once felt as a tense suffix, it was given a wider application, being appended first to other long vowel stems as *ἡ-, ϑη-, στη- φῡ-*, afterward to short vowel stems, and eventually to some mute and all liquid stems.

This theory, it will be observed, explains the reason why we find the ending *-ϰα* applied first to long vowel stems; it is because it originated with such a stem, *δω-*. It explains further the origin of the aorists *ἔϑηϰα*, *ἧϰα*, and two others not usually given in the grammars, *ἔστηϰα* and *ἔφρηϰα*. These aorists were formed after the analogy of *ἔδωϰα* just as *ἔστηϰα* after the analogy of *δέδωϰα*.

It might seem strange, in view of this fact, that we do not find a similar wide extension of the *-ϰα-* aorist, just as of the *-ϰα-* perfect. The reason of course is plain. The same time suffix could not do duty for both tenses. The analogy might have taken its development in the line of the aorist, just as well as of the perfect, and if that had occurred, we should have looked upon it as perfectly natural; but it could not do double duty, serving both as a perfect and an aorist suffix.

As it is, the *-ϰα-* suffix developed in the perfect, and beyond a few *-ϰα-* aorists formed before the suffix had come to be felt as peculiar to the perfect, it took no further development in the line of the aorist.

Such is Brugmann's theory of the *-ϰα-* perfect. It is really less fanciful than one might be at first inclined to consider it. His theory is worked out with rigid method, nothing being assumed, which is inconsistent with known phonetic laws or unsupported by the analogy of the Greek itself and other languages. A demonstration, however, it can not be held to be. It is simply an extremely clever hypothesis supported by striking analogies.

It has met with recognition from German scholars such as von der Pfordten in his *Geschichte des griechischen Perfects*, as well as from Gustav Meyer in his *Griechische Grammatik*. While therefore we may not call it a proof we must admit that it suggests a plausible method by which the *-ϰα-* perfect *may* have developed.

We consider next

OSTHOFF'S THEORY.

For several years after Brugmann propounded his theory it enjoyed general repute as the only plausible explanation yet given of the problem, until the appearance in 1884, of Osthoff's *Geschichte des Perfects im Indogermanischen*. Herman Osthoff, the author of this work is professor of Sanskrit and comparative philology at Heidelberg, and a man of astounding ingenuity in solving the riddles of Indo-European grammar. His mind is constantly evolving a new solution of some knotty point of morphology, worked out with an elaborateness which anticipates every objection that can be raised against it. Although an intimate friend of Brugmann and with him the head of the school of "*Junggrammatiker*", yet he never could feel quite satisfied with Brugmann's theory of the origin of the *-ϰα-* perfect, which we have just considered above.

He consequently set to work to find some explanation which should be more satisfactory, and the result of his lucubrations is given us in a lengthy chapter of the work above cited, pp. 324–390.

Osthoff's theory is that we have in the Greek -*κα*- perfect the particle *κεν*; that *δέδωκα* is *δεδω* + *κεν*.

Let us proceed to the details. And first a few words on roots and the different forms they assume under different circumstances.

It is a generally accepted theory that roots appear under different forms in consequence of accentual conditions. Thus we explain

Skrt. *ás- mi*
ás- i
ás- ti

as having the full form of the root *as*- because accented on the root syllable; whereas the dual and plural forms

svás *smás*
sthás *sthá*
stás *sánti*

take the weakened form of the root -*s* because the accent is on the personal ending. So also in Greek we had originally **δι-δῶ-μι, *δι-δῶ-σι, *δι-δῶ-τι, *δι-δο-τόν, *δι-δο-τόν, *δι-δο-μέν, etc.*, with the strong form of the root *δω*- in the singular, because the accent stands on the root syllable, and the weak form *δο*- in the dual and plural, because the accent is on the personal ending. Of course this primitive accentuation was lost in Greek, before we know it historically as an independent language; the primitive accentual conditions disappeared with the rise of the three syllable law and of the recessive accent of the verb.

So also in the inflection of the noun in Greek. In words of the type of *πατήρ, μήτηρ, etc.*, we have the strong form of the stem *πατερ-, μητερ-* where the stem syllable is accented, as in the accusative singular *πατέρα;* nominative plural *πατέρες;* but we have the weak form of the stem *πατρ-* where the accent falls upon the case ending, as *πατρ-ός, πατρ-ί; πατράσι(ν)* also is formed from the weak stem *πατρ-*.

This variation of the form of the root in two, three and sometimes even four ways (called by the Germans *Stammabstufung*) extends to all parts of speech. It is not limited to nouns and verbs, in which the accent originally shifted, standing now upon the root syllable, now upon the ending, but may occur also in monosyllables, which by their varying force sometimes receive a decided stress and at other times are enclitic.

All parts of speech are equally liable to this change of form dependent upon stress-accent. The phenomenon is witnessed most frequently in case of nouns, adjectives and verbs; yet it occurs also (and this is at present the important point for us) in the case of particles; and we shall soon see that in *κα* we have simply another form of *κεν*, a form bearing the same relation to *κεν*, as our unaccented "the" does to our accented "thé"; or as "come" in "cm in" to our "cóme" in the phrase "you cóme."

The demonstration of this relationship depends upon the principles of the *nasalis sonans* theory, which was alluded to above in connection with *ἔλυσα* for * *ἔλυσm*; and *ἔδωκα* for * *ἔδωκm*. We there saw that this sonant nasal developed in Greek, when unaccented, into *α*; just as in many dialects in Germany the ending *-n* (*i. e.* *–en*) when unaccented becomes a short *e*-vowel, through the medium of the sonant nasal.

The full or strong form of the particle *κεν* is *κεν*. When unaccented it sinks to *κ* + the sonant nasal or **κn*. This sonant nasal then regularly develops to *α* giving us *κα*; just as we have *τατός*, verbal from *τείνω* (root *τεν-*), for **τn-τός*.

The Sanskrit, it may be mentioned, develops the sonant nasal in the same way; thus we have *ta-tás* for *tn-tás*, corresponding to Greek *τα-τός;* and *ta-nó-mi* in the 5th Sanskrit class (acc. to Bopp) for *tn-nó-mi.*

Nor is *κεν* the only illustration, among particles, of this variation of weak and strong form, this *Stammabstufung.*

We have another striking illustration in the case of the particle *αυ*, which has for its weak or unaccented form *-υ*. This unaccented form is seen in *πάν-υ* (*cf.* *πᾶν*) and further probably in *ουτος*, *το-ύ-τον*, *etc.* It is doubtless the same as the Sanskrit particle *-ŭ* and the Gothic *-u*, seen in the passive forms of the optative and imperative, as *nimada-u* and *nimainda-u.*

The same *Abstufung* holds similarly for many other particles, to which Osthoff has devoted some exhaustive consideration in the fourth volume of *Morphologische Untersuchungen*, pp. 222–277, in his consideration of what he calls the "*Tiefstufe im Indogermanischen Vocalismus.*" It is unnecessary to consider this matter further here.

We may now return to *κεν*. We have seen that we have to deal with two forms, *κεν* and *κᾰ*. There are to be sure two other forms of our particle *viz.* *κε* and *κᾱ*, but as they do not concern our present purpose, we omit any consideration of the question of their special origin, interesting as that might be. The form *κα* is confined pretty nearly to the Doric and Lesbic-Aeolic dialects in the historical period; yet this does not constitute any objection against its antiquity, or against its having at some time been in frequent use in all dialects.

So much for the morphological side of the particle. Let us now look at its probable signification.

The tradititional etymology of *κεν* has connected the word with the Skrt. *kám*, which means 'well, indeed, to be sure'; and even the latest scholars have signified their acceptance of this view, including among the latter Delbrück in his *Syntaktische Forschungen*, vols. I., and IV.; Ascoli, *Studj Critici* II., 231 ff; and Gustav Meyer in his *Greek Grammar.* Osthoff is the first to raise objections to this etymology; not, as he admits, because it is phonetically inadmissible, though he mentions one or two weak spots (which we shall have to omit here), but because he thinks he has a better etymology to propose. He thinks *κεν* identical with Skrt.

çám, an indeclinable adjective signifying "beneficent, advantageous, wholesome, good." This word, which has not yet become a particle in Sanskrit, Osthoff thinks became one in Greek and in the signification of the German *wol* united itself in its weak or unaccented form κα with the primitive inflection of the perfect: *e. g.*, δέδω-, to form the -κα- perfect, δέδωκα. δέδωκα would therefore mean "I have indeed given," or as Osthoff puts it in German, "*ich habe wol gegeben.*"

It is in fact this very correspondence in meaning between the Sanskrit *çám* and the German *wol* that leads Osthoff so decidedly to prefer the etymology of κεν which he proposes and advocates. He traces the development of the German *wol* from its Old High German force of "well," through the Middle High German, where it takes on the additional meaning of "quite, very, thoroughly, certainly," until it reaches that force, untranslatable in English, which it exercises with such frequency in the German of to-day, as for example in such expressions as "*Sie sind wol krank*; *das haben Sie wol gesehen.*" Osthoff believes κεν or κα has gone through the same course of development. The Sanskrit *çám* he considers to represent the original signification of κεν, namely "excellently," while in the historical period of the Greek language he thinks he finds clear traces of κεν in the same sense as Germam *wol* in its weak, almost pleonastic force.

The question that naturally first presents itself is: Does κεν actually have this force?

Delbrück, *Syntaktische Forschungen*, I., 90, expresses the opinion that while κεν, ἄν "*begleiten den conjunctiv und optativ durch alle inneren wandlungen, sie erzeugen dieselben nicht. Sie sind nur ein beredter ausdruck dessen, was auch durch den blossen conjunctiv und optativ ausgedrückt wird;*" *i. e.*, the force of the subjunctive and optative does not depend upon the κεν or ἄν but the κεν or ἄν simply adds a more eloquent expression to tbe force already inherent in the subjunctive or optative themselves. If this be true, it accords excellently with the signification which Osthoff wishes to attach to κεν, and we shall then not be surprised if we find κεν joining itself freely with any mode and tense.

Thus in Homer we find κεν with the future indicative as *Α* 139 ὁ δέ κεν κεχολώσεται ὅν κεν ἵκωμαι, which Osthoff would render "*der wird wol zürnen, zu dem ich kommen werde;*" or *Δ* 176 καί κέ τις ὧδ᾽ ἐρέει Τρωων "*so wird wol mancher unter den Troern sprechen;*" and a number of similar instances.

The present indicative also occurs, though rarely, as Ξ 484 τῷ καί κέ τις εὔχεται ἀνήρ "*darum wünscht sich wohl auch mancher.*"

Faesi, in his edition of the Iliad, in commenting upon these and similar passages says that κεν with the future and present indicative does not express any doubt or uncertainty, but a calm confidence, equivalent to that expressed by που, οἶμαι. *Cf.* his notes on *Ψ* 102, 484. In this sense κεν corresponds exactly to the German *wol* in such expression as "*das ist wol* *zwanzig jahre her; ich bin wol zu beneiden,*" where *wol* is quite equivalent to the Greek *πoυ, oἶμαι,* "forsooth, I think, in my opinion."

It is doubtful whether we have any example of the imperfect with *κεν*, as the reading of *β* 104 is uncertain. Only one manuscript reads: *ἔνθα κεν ἠματίη μὲν ὑφαίνεσκεν μέγαν ἱστόν.* The others give *ἔνθα καί;* but of the aorist indicative we have at least one instance, *viz. δ* 546.

> *ἤ γάρ μιν ζωόν γε κιχήσεαι, ἤ κεν Ὀρέστης*
> *κτεῖνεν ὑποφθάμενος.*

Here again we may translate "you will find him alive or (it may be assumed) Orestes has killed him," the *κεν* being equivalent to *wol.* In German we might translate "*oder es hat ihn wol Orestes getödtet.*"

In German *wol* is used with the perfect indicative with great freedom in popular poetry, *e. g.*,

> "*Es ging ein Müller wol über's Feld.*"
> "*Es zogen drei Burschen wol über den Rhein.*"
> "*Ein Knäblein ging spazieren wol um die Abendstund.*"

That no example of the perfect indicative with *κεν* in Homer is found, Osthoff regards a matter of chance, to be explained by the rarity of the perfect indicative in the epic or narrative style.

So much for the form and signification in which *κεν, κα* has attached itself to the primitive perfect to produce the *-κα-* perfect. Let us now note the successive stages of the process by which the *-κα-* inflection became established throughout the whole perfect indicative and subsequently throughout the whole perfect system. First let us set clearly before our eyes the original inflection of the perfect indicative active of a Greek verb, such as those among which we know the *-κα-* perfect to have arisen, *viz.*, long vowel stems. Let us take the stem *στᾱ-* (Ion., Att. *στη-*). The early Greek inflection of this perfect (though not the earliest) was probably

Singular.	Dual.	Plural.
**ἕστη* (for **ἕ-στη-α; cf. λέ-λοιπα*)		*ἕσταμεν*
**ἕστης* (for **ἕ-στη-ας; cf. λέλοιπας*)	*ἕστατον*	*ἕστατε*
**ἕστη* (for **ἕ-στη-ε; cf. λέλοιπε*)	*ἕστατον*	*ἕστασιν*

The stages of development are as follows:

1. By the union of the *κα* with the original 1st singular **ἕστη* we get *ἕστηκα.* Further illustrations of this perfect from long vowel stems are:

> *δέ-δη-κα* (*δέω* 'bind') Aeschylus, Andocides.
> *τέ-θη-κα,* later *τέ-θεικα,* after the analogy of *εἶκα.*
> *δέ-δω-κα.*
> **γέ-γνω-κα,* later *ἔ-γνω-κα.*

2. In the second stage we find that the *-κα-* perfect has extended its inflection from the first singular in *-κα-* to the second singular in *-κας* and

the third singular in *-κε(ν)*. In this step it has, of course, simply adopted the regular perfect inflection as already existing in the language and exhibited in such words as *πέποιϑα, πέφευγα, ἔρρωγα, etc.* The *-κα* inflection, however, has not yet strayed beyond the limits of the singular. The dual and plural show no traces yet of the *-κα*, as seen in such words as

	γέγηκα,	pl.	*γέγαμεν*
	βέβηκα,	pl.	*βέβαμεν*
	τέτληκα,	pl.	*τέτλαμεν*
	τέϑνηκα,	pl.	*τέϑναμεν*
	ἕστηκα,	pl.	*ἕσταμεν*
even	*δέ-δω-κα,*	pl.	*ἀπο-δε-δό-ανϑι* Cauer ^{2} 298.

This second stage is characterized further by the formation of new *-κα-* perfects, but only from long vowel stems; and these new formations have, like their models, the *-κα-* inflection only in the singular. This is about the stage represented in the Homeric epics. For out of the hundreds of instances of the *-κα-* perfect in Homer, all formed from long vowel stems, we have only five instances of a plural *-κα-* perfect, *viz:*

ἑστήκασιν	*Δ* 434
κατατεϑνήκασιν	*O* 664
πεφύκασιν	*η* 114
τεϑαρσήκασιν	*I* 420,687

3. The *-κα-* inflection extends itself throughout the entire indicative, and also throughout the rest of the perfect system, *i. e.*, the subjunctive, optative, infinitive and participle. This stage is represented in general by the post-Homeric Greek, though an incipient tendency of the *-κα-* forms to extend themselves is seen in Homer, in the sporadic occurrence of a few plural indicatives and a few perfect participles.

With this the development of the *-κα-* perfect may be considered complete. Some interesting changes in the Ablaut occurred, which may be left unmentioned.

Osthoff finds in certain Sanskrit forms what he considers a powerful support of his theory of the Greek *-κα-* perfect. These forms are the Sanskrit perfects:

dadâu, dadhâu, papâu, tasthâu.

Osthoff thinks that here we have original perfect forms with the added particle *-u*.

da-dâu is therefore simply *da-dâ-u, etc.*, this *-u* being the same particle that we have already noticed as occurring in the Gothic *nimadau, nimaidau*.

Any one familiar with the Sanskrit sandhi-rules will see at once an objection to this theory, since *pa-pâ-u, da-dâ-u, etc.*, ought, according to the laws of Sanskrit phonology, to give not *pa-pâu, dadâu but papó da-dó.*

Osthoff, however, maintains that the composition of the root with the particle antedates the historical period of the Indian language and that we have in *da-dâu, etc.*, the legitimate successors of an Indo-European *de-dó-u.* Whitney in his *Sanskrit Grammar* (§ 800 c of the German ed.) cites two forms from the Rig Veda of perfects from *â*-stems in simple *â*, not *-âu*, *viz.: paprâ, jahâ* (*prâ-?, hâ-* "follow"), instead of *paprâu, jahâu.* This would seem to indicate that roots in *-â* originally formed the perfect in *-â*, and if that is so it would be natural to see in the forms in *-âu* traces of an added *-u* as Osthoff does. If now, reasons Osthoff, the Sanskrit employs the particle *-u* in a perfect formation by adding it to the 1st and 3rd singular of long vowel stems, what more natural than that the Greek should do the same with *κεν?*

Osthoff's theory then, briefly stated, is that the particle *κεν* in its weak or unaccented form *κα*, a form actually occurring in several Greek dialects, became added to the original perfect forms of long vowel stems, first to the 1st and 3rd singular, and that it afterwards extended its range over the entire perfect system; and the analogy of the Sanskrit perfects in *-âu* is appealed to, to substantiate this view.

Is this a probable theory? It seems to me that it does have a good deal to commend it to our favorable consideration.

1. As to the amalgation of different words into one word in the individual Indo-European languages we need have no hesitation. Instances are frequent of the union of an inflected form with a particle, or of two inflected forms with each other, as may be seen, *e. g.*, in the Gothic *liuganda-u, nimaida-u* (Greek *νέμοιτο*), in the French *j'aimer-ai*, Latin *vēneo*, (for *vēnum eo*), *calefacio, fervefacio, etc.*, and, as I incline to believe, also in Sanskrit *dadâu, etc.* As to the form *κα,* it is only what we should be compelled to assume as the weak form of *κεν,* even did we not know of its actual existence in several of the Greek dialects. That the form *κα* therefore should combine with the original perfect is not at all unlikely.

2. As to the exact etymology of *κεν* (*κα*) I conceive that that really concerns the main question very slightly. It is immaterial whether *κεν* be the same as the Sanskrit *kam* or *çâm*, or in fine neither the one nor the other. It is certainly an independent word of the Greek language and as such can unite with an already existing inflectional form to create a new form. If it really be the same as the Sanskrit *çâm* and has gone through the same semasiological development as the German *wol* so much the better, though neither of these facts is necessary to our theory.

3. To my mind it can hardly be fortuitous that we find the origin of the *-κα-* perfect in Greek in those very stems, which in Sanskrit we are led to look upon as compounded in their perfect formation, with the particle *-u, viz.*, the long vowel stems. To be sure we find this *-u* in the Sanskrit perfect only in the 1st and 3rd singular; yet we must bear in mind that in Greek also the perfect in *-κα* was for a long time confined to the singular of the indicative, and that practically only in the post-Homeric Greek did it extend its range beyond this.

It should further be borne in mind that the three identical roots which furnish us with the earliest specimens of the Greek -κα- perfect are also Sanskrit roots in -*â*, which form the perfect in -*âu*. Thus we have side by side the roots

στᾱ- (Ion., Att. στη-)	*sthâ-*
δω-	*dâ-*
θη-	*dhâ-*

And the perfects

ἕστηκα	*tasthâu*
δέδωκα	*dadâu*
τέθηκα (τέθεικα)	*dadhâu*

It would seem as though these possessed some innate tendency to join to themselves a completing element, and if that be so what other element can this be for the Greek than κα, and what can κα be but the particle κεν in its weak form?

4. As to the non-occurrence of κα with the perfect indicative in any historical monuments of the Greek language, we need not feel any surprise, such as Curtius does, in his critique of this theory, in his *Zur Kritik der neuesten Sprachforschung*, p. 152 f. Curtius considers in fact that the non-occurrence of the particle with the perfect indicative is sufficient ground for condemning the whole theory, which he proceeds to do very summarily.

But let us consider a moment. By the very terms of the hypothesis, it must have been at a period considerably prior to the oldest monuments of the Greek language that the particle κα become united with the already existing perfect inflection to form the -κα- perfect. At that time the particles κα, ἄν and very likely many others enjoyed a much freer use and wider application than later, when the language had become more stereotyped. Certainly at the beginning of the historical period of the Greek language κεν and ἄν had become appropriated to certain distinct uses and were confined to them. Not only do we not find either κεν or ἄν with the perfect indicative in Homer, but it is only with the greatest difficulty that we succeed in gathering together a few instances of its use with the present and future indicative. Even if we had discovered one or two instances of it with the perfect indicative it would not have materially favored our theory.

It seems to me, therefore, that Osthoff's theory exhibits an unusually keen perception and fine appreciation of the principles governing linguistic development, and that, while it cannot, any more than Brugmann's, be called a demonstration, yet it is as probable and even more instructive.

HARTMANN'S THEORY.

Hartmann's theory appeared first in *Kuhn's Zeitschrift*, vol. xxviii. p. 284, in a brief article entitled *Wieder einmal das κ- Perfectum.*

Hartmann starts with the declaration that the -κα- perfect could take its origin only from such stems as possessed a gutturally extended form by the side of the original one. Thus *πτώσσω* for (**πτωκ-ι̯ω*) which points plainly to a stem *πτωκ-*, as an extension of the stem *πτ-* (*cf.* *πί-πτ-ω*), gives the perfect *πέπτωκ-α*. This *πέπτωκα*, being associated with *πί-πτ-ω* as its perfect naturally gave rise to the conception of *-ωκα* as the perfect suffix, whence arose such forms as *ὄχωκα*, *οἴχωκα*, possibly even *ἐδήδοκα*.

This is intended to serve only as an illustration of the method to be followed in seeking the origin of the *-κα-* perfect. Hartmann admits that the relation between *πτ-* and *πέπτωκα* could only give us *-ωκα* as a perfect suffix (as seen in *ὄχωκα*, *οἴχωκα*), not *-κα*. He is consequently led to seek further in search of some analogy which shall be more far-reaching in its effects. He thinks he finds this in the relations existing between *βάσκω* and *βέβηκα*. He explains *βέβηκα* as the perfect of *βάσκω* properly, not of *βαίνω*, and as arising by proportional analogy. Just as *λάσκω*, which is a real guttural stem (being for **λακ- σκω*, *cf.* *ἔ-λακ-ον*, aorist), forms its perfect *λέληκα*, so after the same analogy *βάσκω* (though not really from a guttural stem) forms the perfect *βέβηκα*.

After *βέβηκα* had once come into existence the analogy extended to other presents in *-σκω*, *e. g.*, *ϑνήσκω*, *βλώσκω*, *βιβρώσκω*, *etc.*, whence the perfects *τέϑνηκα*, *μέμβλωκα*, *βέβρωκα*; then subsequently to other stems.

Such in brief is Hartmann's theory, though his own statement of it is exceedingly unfortunate and obscure. It will be seen that it resembles Brugmann's theory quite closely. I hold it, however, as much less probable than Brugmann's for three reasons.

1. The analogy by which *βάσκω* is supposed to form its perfect *βέβηκα*, *viz.*, from the relation existing between *λάσκω* and *λέληκα* is not at all plausible. There is no similarity of meaning between the two words which would tend to associate them together in the mind, nor is *λάσκω* a common word or one which from the frequency of its use would be expected to exercise an influence upon other word-forms.

2. There is no evidence that the form *βέβηκα* is more recent than *λέληκα*, as is implied by the terms of Hartmann's theory. Both forms are found in the oldest monuments of the Greek language, but nothing tends to show that *λέληκα* existed before *βέβηκα*, so as to serve as the model for the formation of the latter.

3. It is not likely that a formation taking its origin from a present with a *short* vowel, like *βάσκω* should operate immediately in affecting presents with a *long* vowel as *ϑνήσκω*, *βλώσκω*, *βιβρώσκω*, *etc.*, while at the same time failing to influence presents with a short vowel, such as *βόσκω*, *φάσκω*, *etc.* On the other hand we should expect these short vowel presents to be first affected by the analogy, and the long vowel presents later, if at all.

ON SOME METAMORPHOSED ERUPTIVES IN THE CRYSTALLINE ROCKS OF MARYLAND.

BY WM. H. HOBBS.

Recent studies of the crystalline rocks, while they leave us still in doubt as to the origin and much of the subsequent history of the so-called *fundamental complex* (*Urgeneiss* or *Grundgebirge* of *Germans*), yet have been very successful in explaining satisfactorily many areas of crystalline schistose rocks by the metamorphism of sedimentary layers or eruptive masses. Thus many areas of rocks not to be distinguished in the hand specimen from schists which lie below the lowest fossiliferous horizons, have been shown to be metamorphosed sediments of Silurian, Devonian, or even younger ages. In Norway and in western New England, Silurian beds have been changed to crystalline schists. Schistose Devonian rocks occur in the Ardennes and Taunus. In northern Italy, at Carrara, the Trias is represented by marble and in other localities crystalline schists are assigned to the Cretaceous.

In seeking to analyze more carefully the process and find analogies with other metamorphosing agencies, the attention is directed at once to those processes which take place within the contact-zones of eruptive masses. Careful comparison shows that as concerns mineral decompositions and the atomic and molecular re-arrangements, the two processes yield remarkably similar results. The hydrous minerals generally disappear, certain mineral species disappear and are replaced by other species formed from their constituents, which are more stable under the conditions of the process. The more common metamorphic minerals are mica, garnet, staurolite, epidote, vesuvianite, wollastonite, and certain varieties of pyroxene and hornblende. Analyses *in toto* of the unaltered and metamorphosed phases of the same rock yield identical results, exceptions being noted when tourmaline, topaz, or allied species, in whose formation gaseous material is concerned, have been developed during the process. Mineralogically, then, the process consists in a more or less thorough rearrangement, which may be mainly molecular as in the case of hornblende after augite, but it more frequently involves elaborate chemical decompositions and reactions. The German expression, *Umbildung*, aptly describes this process.

If the agent be sought which affects the transformations, we are directed to a different source in each of the two cases of Contact and Regional metamorphism. In the first it is without question, heat, while in the second we are forced to believe that heat, if a factor at all, is a very small one, its place being taken by pressure, accompanied by internal movement. Where the rocks show most disturbance in the field, there the microscope reveals the maximum of pseudomorphic change and alteration of texture.

We see then, that much the same effect can be produced at least along two different lines, and from what has been said about the chemical composition of the rock before and after the process, it would not seem to be impossible to produce by metamorphism from a shale and a gabbro, the same resultant rock, provided their analyses *in toto* were the same.

The study of metamorphosed massive rocks has yielded perhaps the most satisfactory results, since the original character is frequently betrayed even after pronounced metamorphic action, by areal or structural relations, or by the remains of rock-textures. The sending of dikes or apophyses into surrounding rocks, the presence of included fragments of them, and the remains of crystal boundaries now existing for some other species known to be secondary, are valuable bits of evidence. In some regions where massive gabbro or diabase occurs in conjunction with hornblende gneisses, it is seen that they pass insensibly into one another, and careful study has shown that the hornblende gneiss is the metamorphosed form of the gabbro. Geologists have further been able to trace the steps of the process by examining the rock from parts of a given area that have been but slightly effected, at localities where most disturbance has taken place, and at intermediate points. It would seem that the feldspars are the most sensitive to disturbance, a wavy extinction between crossed Nicols being noticeable when the other minerals show no effects. If the process is more advanced, a breaking up of this mineral may result, and one of the decompositions to saussurite, epidote or amphibole may be noticed. Pyroxene is altered to amphibole (Uralitization). A breaking up of hornblende crystals takes place with an arrangement of the longer axes of fragments parallel to a plane of schistosity. The details of the process differ somewhat according to the original chemical and mineralogical composition of the rock, the intensity of the matamorphism, and other conditions which we can not analyze.

A region which furnishes an example of the metamorphism of gabbro to hornblende-gneiss is that southwest of the city of Baltimore. The Potomac formation (Juro-Cretaceous) consists in this vicinity of unconsolidated gravels which rest on the crystalline schists and gneisses of the Pre-Cambrian belt, and their included intrusive members. To the west and northwest of the city of Baltimore is a nearly circular area of hypersthene-gabbro and gabbro-diorite, which has become well known through the beautiful studies of Dr. Geo. H. Williams. The results have been published in a bulletin of the U. S. Geological Survey. Professor Williams has shown that the hypersthene-gabbro of that area passes into gabbro-diorite by the alteration of both hypersthene and diallage to hornblende. The alteration begins on the surface of the pyroxene and proceeds from there toward the center. From the same hand specimen sections were prepared in which could be seen almost unaltered pyroxene, and the same mineral with wide marginal fringes of hornblende. In the hand specimen the hypersthene-gabbro possesses a bronzy lustre from the preponderance of orthorhombic pyroxene, while the gabbro-diorite is green, owing to the secondary hornblende derived from pyroxene.

An area five miles square immediately southwest of that just described, I have examined in the field and studied by means of microscopic sections and otherwise in the laboratory. The western portion of the area is occupied by the Pre-Cambrian gneisses. The remaining portion of the area contains outcrops of gabbro, gabbro-diorite, true diorites, hornblende gneiss, and intrusive rocks which belong to later periods of eruption. The field study shows that the gabbro forms a continuation of the gabbro area studied by Professor Williams. This part of the gabbro area, however, differs in two respects from that farther north; first, in the greater differentiation of the magma, which here produced true diorites as well as gabbro; and, second, in the greater metamorphic action, which has produced from the gabbro first a gabbro-diorite, and then a hornblende gneiss. The true diorites have gone over to hornblende gneiss by much the same process as the gabbro-diorite. These several modifications are assumed to have formed one and the same magma from the absence of any visible contact between them. The gabbro and diorites have not been found in the same outcrop, but the field evidence is such as to make it very probable that they are differentiations of the same mass. Gabbro, gabbro-diorite, and hornblende gneiss on the other hand, can be seen to pass imperceptibly into one another in the vicinity of Ilchester. The microscopic evidence is most confirmatory on this point, slides having been prepared from a sufficient number of specimens to show the steps in the process. To make clear, it will be necessary to give somewhat in detail the characters of the end types, gabbro and hornblende-gneiss, and of the intermediate varieties.

Fig. 1.— Section of gabbro-diorite from Ilchester, Md., showing reactionary rims between feldspar and hornblende. X 50.

The entirely unaffected hypersthene gabbro has not been found within the area studied, but a rock containing both hypersthene and diallage surrounded by marginal fringes of green hornblende, composes a core a few feet in diameter enclosed in gabbro-diorite. This core occurs in the wall of rock formed by the railroad cutting at Ilchester station, and its brown color makes it apparent in contrast with the green of the surrounding rock. The feldspar of this rock is a basic plagioclase, corresponding closely with bytownite. Between crossed Nicols its strained condition is apparent in the wavy extinction. The hypersthene is strongly pleochroic, and, like the diallage, has the usual characters except for the marginal rim of hornblende.

The gabbro-diorite contaius neither hypersthene nor diallage, both having been changed completely to hornblende. This mineral is not generally so fibrous as that of uralitized diabases, but it is a green massive variety in crystals not many times smaller than those of the pyroxene from which they are derived. Not infrequently the central portions contain areas, roughly circular, of a colorless mineral of low refractive index, which is believed to be quartz separated in the alteration process, and indicating that its host is less acid than the original pyroxene. Similar areas occur in the hyperite-diorites of Sweden and in the Baltimore gabbro-diorite. The feldspar is bytownite, but here it shows more marked optical anomalies than in the gabbro. In the more effected specimens, hornblende is developed in needles within the feldspar, being sometimes arranged in bands and indicating, it would seem, lines of weakness. In certain of these specimens a distinct reaction-rim appears between the feldspar and the hornblende. Between crossed Nicols this rim affords high colors like those of epidote. Epidote was found by Dr. Williams to compose reaction-rims in the gabbro-diorite of Mount Hope, and it was at first suspected that these aggregates might be composed largely of epidote. Prof. Rosenbusch suggested to me that the mineral is amphibole in thin scales, the high colors resulting from intercalated films of air. (Fig. 1.)

In some specimens of this rock rutile is present as an important accessory constituent, associated with ilmenite, and both are surrounded by wide rims of titanomorphite or sphene. (See Fig. 2.) In a few localties (Ilchester R. R. cut) these minerals can be seen in the hand specimen, where they closely resemble the similar association in the hornblende gneiss of Lampersdorf in Silicia. As soon as the rock takes on the laminated character of a gneiss, the feldspars appear broken down or granulated peripherically into fine mosaics (*Randliche Kataklassstruktur.*) Simultaneously a "fraying out" and splintering of hornblende, and a considerable development of epidote are to be


Fig. 2.—Section of gabbro-diorite from Ilchester, Md., showing ilmenite, rutile and titanomorphite. X 275.

are to be observed. The splintered fragments of hornblende and the newly-formed minerals become roughly oriented with reference to a plane of schistosity. (See Fig. 3.) Plate I is from a photograph of the wall of hornblende gneiss on the left bank of the Patapsco river opposite Ilchester railroad station. In the same region are found other younger intrusive masses which cut the rocks just described. The most important of these is a porphyritic granite containing allanite-epidote intergrowths, and having dioritic facies resembling the diorites associated with gabbro. Isolated bosses of a non-feldspathic pyroxene rock and a coarse hornblende picrite (Cortlandtite) occur. Further, a coarse pegmatite is especially abundant in the neighborhood of Ilchester.

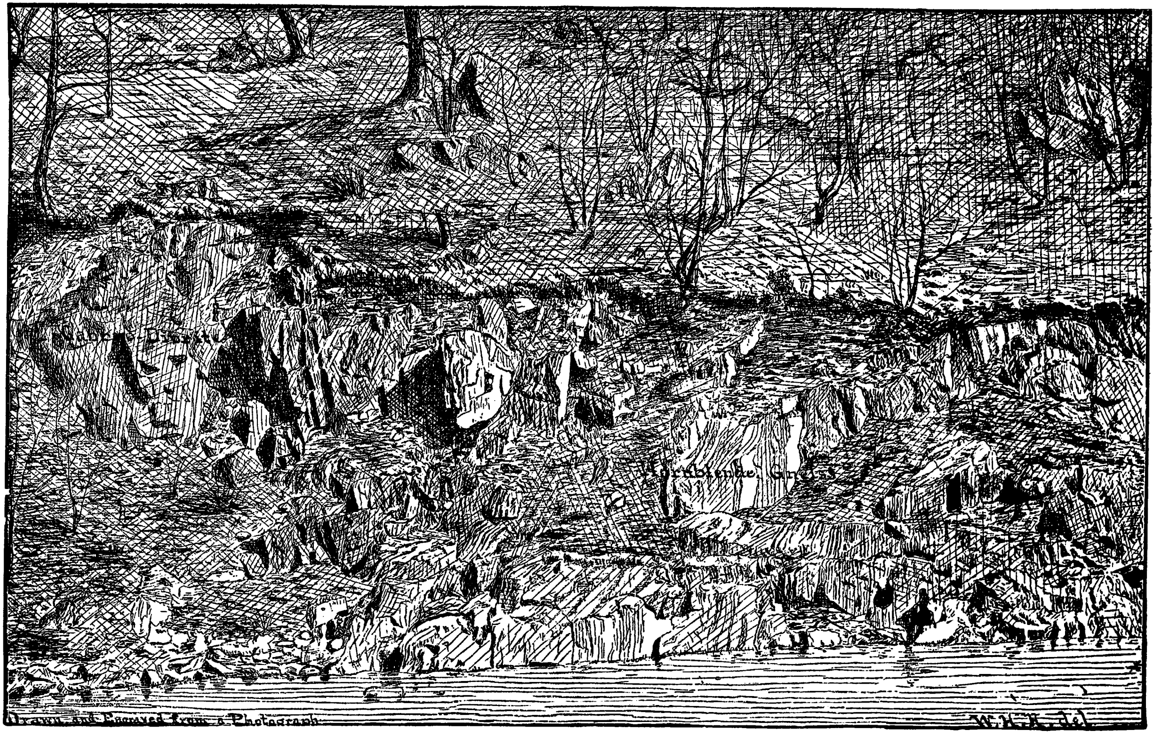
Fig. 3. Section of Hornblende-Gneiss (Metamorphosed hypersthene gabbro) from Thistle Cotton Mills, Ilchester, Md., showing peripheral granulation of feldspar, fraying out of hornblende, and development of epidote with zonal structure. X50.

In the course of a hasty reconnaissance in the Odenwald in Hesse, I was much impressed by the striking resemblance in characters of the rocks of that region and of the one just described. The porphyritic hornblende granites and diorites of the Birkenauerthal resemble more than any others that I have seen the Ilchester granite. In the vicinity of Burg Frankenstein on the Bergstrasse occur gabbros associated with dioritic rocks bearing much resemblance to the gabbro-diorites of Ilchester. The Ilchester Cortlandtite finds its representative in the *Schillerfels* of Schriesheim. The analogy might be carried further to include a pegmatite and a basic pyroxene rock (Wehrlite) from the same general locality in the Odenwald region.

EXPLANATION OF PLATE.

Gabbro-diorite passing into hornblende gneiss. On left bank of Patapsco river, near highway bridge, at Ilchester, Md. The gabbro-diorite is seen on the left, passing by insensible gradations into hornblende gneiss toward the right.

Plate IV


Dikes
Hornblende Gneiss
Drawn and Engraved from a Photograph
W. H. H. del.

NOTES AND A QUERY CONCERNING THE ERICACEAE.

By CHAS. H. CHANDLER, Ripon, Wis.

Plants of the Heath Family are rarely found in regions where the soil is calcareous. The personal search of the writer in his leisure hours for some years, as well as inquiries made of botanists acquainted with the flora of several states, have disclosed no examples of Ericaceae in such regions except such as by their peculiar conditions seem to be exceptions tending to prove the general rule of their absence.

The only vigorous growth found under such conditions has been that of the parasitic Monotropa, reported by several observers; but since its support is thus indirectly obtained from the soil, its growth is not inconsistent with the statement that the Ericaceae will not tolerate compounds of lime.

Rare and feeble specimens of Pyrola rotundifolia are said to have been found in Ripon, Wis., in a region of Trenton limestone. But, as nearly as the two spots in which it was found can now be determined, they were both upon knolls of drift gravel, where the effects of the underlying limestone must have been very slight, if not entirely absent.

A vague account has been received of some one of the smaller species, Vaccinium having been found in or near Waupaca county, in a region of hard water. But here too it may be reasonably suspected that the conditions were like those mentioned in the case of the Pyrola, since the Vaccinium was said to have been found in a region of knolls, and upon the knolls rather than between them.

No other apparent exceptions have been found to the rule that calcareous soils are unsuited to the growth of all members of the Heath Family, and this to a degree which is practically prohibitive.

Several specimens of Kalmia latifolia, upon being carefully transplanted into a soil of weathered limestone and clay in Greene county, Ohio, died at once; and others set in a black vegetable loam filling a long depression in the same soil lingered without any growth for some months and then died

The query whether it is possible for any member of the Ericaceae to grow in a calcareous soil may lead to broader questions which have received very little attention from either writers on agriculture or botany, such as whether the non-adaptability of certain soils to certain plants may not often be due as much to the positive presence of injurious constituent as to the negative property that certain food elements demanded by the plants are absent; and whether such lines of adaptability do not frequently coincide with generic or family division lines.

NOTE.— After the reading of this paper cases were cited by members present showing real exceptions to the rule suggested. Gaylusacia resinosa is found upon Trenton limestone three miles west of Hanover, Ind., on the high banks of the river. Both Gaylusacia and Vaccinium on hill tops of Lower Magnesian limestone in towns of Troy, Franklin and Spring Green, Sauk county, Wis., and other plants of this order, but the species were not named, in Lincoln county, Ky. In none of these cases, however, did it appear that the drainage from limestone would come to the plants; but still the soil must be calcareous.

ARTIFICIAL KEYS TO THE GENERA AND SPECIES OF MOSSES RECOGNIZED IN LESQUEREUX AND JAMES'S MANUAL OF THE MOSSES OF NORTH AMERICA.—ADDITIONS AND CORRECTIONS.

BY CHARLES R. BARNES.

Since the separate publication of the Keys printed on pages 11–81 of this volume, the author has discovered a number of errors, typographical and other. He is also indebted to Mrs. E. G. Britton, Miss C. E. Cummings, Mr. E. A. Rau, Dr. C. W. Swan and Mr. L. S. Cheney for suggestions or corrections. The additions and corrections which have thus accumulated are deemed of sufficient importance for publication.

Page 18, for first three lines under ¶ ¶ ¶, substitute:

Teeth bifid to the common membranous base.
Leaves subulate to lance-subulate, from a broader base . . . . **Leptotrichum**, 105. **37.**
Leaves broader.
Lid short, conic or beaked . . . . . **Desmatodon**, 110. **38.**
Lid elongated-conic . . . . . . **Trichostomum**, 108. **38.**

Page 23, for line 12, substitute:

Leaf-cells quadrate at basal angles.
Plants small, capsules about 2mm. long . **Platygyrium**, 307.
Plants large, capsules about 4mm. long **Cylindrothecium**, 310. **67.**

Page 25, below B. 1, insert:

[**SS. cymbifolium** and **papillosum** may be sought here.]

Page 28, for line 15, substitute:

Costa broad above, almost or quite filling point.

Page 30, under **DICRANELLA**, read:

I. *Cells of the exothecium rectangular-quadrate; seta red; costa narrow and well defined below.*

Page 31, line 1, read:

II. *Cells of the exothecium prosenchymatous; seta often yellow; costa usually broad and indistinct below.*

Page 32, set **D. palustre,** 19. opposite line 11 and dele lines 12 and 13. For line 19, substitute:

Papillose at back.
  Capsules solitary . . . . **D. spurium, 21.**
  Capsules clustered . . . . **D. Drummondii, 22.**

Under 2, dele line **a.**

Page 33, line 13, for **b,** substitute **B.**

Page 43, after line 15, insert:

[**G. Pennsylvanica** will be sought here.]

Page 47, for last 3 lines, substitute:

Capsule wholly exserted.
  Smooth when dry, defluent into seta . . . . **O. lævigatum, 2.**
  Furrowed when dry, abrupt at base . . . . . **O. Douglasii, 6.**[1]

Page 48, for line 5 from bottom, substitute:

Capsule furrowed when dry . . . . . . **O. Douglasii, 6.**[1]

Page 64, under **NECKERA**, in lines 2 and 4, read:

Plants slender (shoots 1—2 mm. wide), etc.
Plants robust (shoots 3—4 mm. wide), etc.

Page 65, to **Hookeria Sullivantii,** add foot note:

Müller writes (July 18, 1888): "Die *Hookeria Sullivantii* mihi unterscheide ich auch heute noch von *H. lucens* und ebenso von *H. acutifolia* aus Indien." *Fide* Mrs. E. G. Britton.

Page 66, under **THELIA**, for last two lines, substitute:

Usually bi-furcate, teeth long (1:17—20), leaves ciliate **T. asprella, 2.**
Usually 4-furcate, teeth short (1:12), leaves not ciliate **T. Lescurii, 4.**

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[1] The position of the stomata of this species is still uncertain, and until it is found again no more definite characterization of it seems possible.

Page 69, under ++ ++, for lines 2, 3 and 4, substitute:

Stem leaves short acuminate, cilia 2, annulus double . **H. scitum, 8.**
Stem leaves long acuminate, cilia 3, annulus simple . **H. gracile, 10.**
Stem leaves long acuminate, cilia 1, annulus 0 . **H. calyptratum, 11.**

Under -+- -+-, for lines 4 and 5, substitute:

Apical cells of branch leaves round, papillose . **H. delicatulum, 14.**
Perichætial leaves not ciliate, apical cells of branch leaves oblong, with 2—3 papillæ . . . . **H. recognitum, 13.**

Under **b** insert as line 6:

Plants minute, leaves entire (but papillæ salient), costate to the middle . . . . **H. pygmæum, 7.**

Page 70, * * , substitute:

* * *Leaves entire, or denticulate above, plants creeping.*

Page 71, under ¶ ¶ insert, as line 1:

Leaf cells rhombic above, rectangular below **H. occidentale, S. & L.**[1]

Change the co-ordinate choices in this paragraph, lines 6 and 12, so as to read:

Leaf cells alike throughout.
Leaf cells enlarged, rectangular at the basal angles.

Page 73, insert as line 8 from botton:

Leaves broad-ovate, acute, segments split . . **H. hians, 77.**

Page 74, for line 3, substitute:

Deltoid, with long slender points (leaves of branchlets sometimes blunt).

Page 75, for line 8, substitute:

Leaves widest above base, long acuminate.
Leaf cells oblong, parenchymatous . . **H. chrysophyllum, 130.**
Leaf cells fusiform, prosenchymatous . . . **H. riparium, 127.**

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[1] **Sull. Icon. Musc. Suppl. 105. pl. 81.—Accidentally omitted from the Manual.**

Page 76, for last 10 lines, substitute:

Leaves not falcate.	
Abruptly filiform apiculate, alar cells not conspicuous	**H. trichophorum**, 100.
Gradually filiform acuminate, alar cells orange.	
Plants slender, 2—3 cm. long.	
Branches erect, leaves serrate . .	**H. Muhlenbeckii**, 111.
Branches intricate, leaves nearly entire .	**H. Fitzgeraldi**, 112.
Plants stout, 7—10 cm. long, leaves quite entire	**H. stellatum**, 131.
Acute or short apiculate, alar cells few, large .	**H. palustre**, 165.
Obtuse, entire, alar cells hyaline . . .	**H. cuspidatum**, 176.

Page 78, under II, in parenthesis, dele:

and **Brachythecium Thedenii.**

The following typographical errors should also be corrected:

Page 13, line 1, for nothing read noting.
Page 15, line 10 from bottom, for 153 read 152.
Page 22, line 4, for **B** * read **2** *.
Page 53, line 20, for P. Muhlenbeckii read **P. Mühlenbergii.**
Page 60, line 7 from bottom, for A. augustatum read **A. angustatum.**
Page 69, line 16 from bottom, for H. abietiuum read **H. abietinum.**

THE RELATION OF OLD ENGLISH 'REOMIG' TO GOTHIC 'RIMIS.'

BY G. H. BALG.

The following discussion is the concluding part of my paper on "The Science of the English Language in the Light of Gothic," read before the Wisconsin Academy of Sciences, Arts and Letters, December 28th, 1888.

A number of Germanic stems in *-as : is*, both concrete and abstract, have been given by Sievers, in his Old English Grammar, by Kluge, in a review of that grammar ('Anglia,' vol. V, part 4), by 'Paul, in Paul and Braune's Beitræge' (vol. IV, p. 415; VI, p. 229), by Kluge, 'Nominale Stammbildungslehre' (§§ 84 and 145), and elsewhere. The above suffix answers to Gr. *ος : ες*, in neuter substantives like *γένος*, gen. *γένους* contracted from *γένεος*, for a more ancient **γένεσος;* and to Lt. *us:er*, in *genus*, gen. *generis*, for **genesis.* The accent fell on the radical syllable, and, therefore, in Germanic the suffixal *s* changed into *z* which appears in Gothic as *s* when assuming the final position, but, by leveling, there occurs *z* for *s*, and *s* for *z.*

The Gothic word *rimis*, 'rest, quietness,' shows *s* in all cases. Its original stem, *rimiz-*, answers to pre-Germanic *remez-*, from root *rem* seen in Gr. *η-ρεμ-ος*, *ἥ-ρεμ-αῖος*, 'quiet,' *ἥ-ρεμ-ία* 'rest.' According to the law that pre-Germanic unaccented *e* changed into *i* in Germanic, and pre-Germanic *accented e* became *i* in Germanic, when the following syllable contained *i* (Comp. Gr. *πόδ-ες*, Germanic **fôt-iz*, primitive Old English fêt-i, by *i*-umlaut of *ô* and loss of *-z;* later *fête*, Middle English *fêt*, Modern English *feet*), pre Germanic *remez-* first became *remiz-*, and then *rimiz*(=rimis), our Gothic word in question. Furthermore, Germanic unaccented *i* after a short root syllable was first retained as *i* in Old English and afterward weakened to *e.*

According to the above laws of development and decay, Germanic *remiz* (Goth. *rimis*) appeared in Old English as *remi : rimi : rime.*

Now I claim that *rime* is found in Old English *reomig*, 'quiet,' formed by means of the Germanic adjective suffix *-ag-*. The dark vowel of *-ag* changed the *i* of *rime* (the final vowel of which was dropped) into *io*, **rimag* becoming *riomag*, later **riomeg* (by weakening). But there is another Germanic suff., *-îg* (=Goth. *-eig-; -ag-*= Gothic *-ag-*), which was likewise used to form adjectives from substantives. In Old English *-îg* was first shortened to *-ig*, and in the inflected cases weakened to *-eg*. In consequence of this weakening, the two suffixes *-ag* and *-eg* coincided in the inflected cases, and, by the law of analogy, there occur not only nominative cases with original *-ig*, but also such with *-ig* for *-eg*, from original *-ag*; an example is our Old English adjective **riomig*. A similar case of confusion is that of Old English *io* from *i*, and *eo* from *e*, a fact supported by numerous examples. It is owing to this double confusion that Old English *reomig* stands for **riomeg*; hence, Old English *reomig* is derived from **rime*= Gothic *rimis*.

ARISTOTLE'S PHYSICS (PHYSIKE AKROASIS) REVIEWED.

BY JOHN J. ELMENDORF. S. T. D.,

Professor of Mental Philosophy in Racine College.

An attempt to revivify Aristotle's Physics, when this nineteenth century is drawing to its close, may seem to some an absurd anachronisn. His misstatements of facts have furnished stock quotations to those who would illustrate the ignorance of benighted antiquity. His *a priori* method has been only subject for ridicule, because in this enlightened period there is only one secure path to true scientific knowledge, sc., the slow, but safe road of accurate observation and careful experiment. If the critical observer, from without the sacred precincts, remarks that empirical science manifestly contains *a priori* assumptions which indicate the line, *among* an infinitude of lines, which experiment shall follow, and is stated under the form of concepts which need accurate definition, the reply may be that advanced science is proceeding on the straight and lowly road of "phenomenology," and confines itself to that. The critic might reply, with Aristotle, that there can be no such thing as a science of phenomena, because they must be appearances of some thing, and cannot be thought or described, much less *accounted for*, without some assumption, true or false, respecting that thing. But the dispute would only grow more lively, and the end be far off. The critic will, perhaps, be safer in confining himself to the remark, that so long as the experimenter says, "I see that," no meaning can be attached to the purely phenomenal construction of his words, to-wit.: "A chain of successive (subjective) states called, *I*, is at this moment followed by the subjective state called, *seeing* one of co-ordinate phenomena called *that*." Since pure phenomenology appears to be reduced to this, so much the worse for phenomenology.

Logic, pure mathematics, even that despised thing called metaphysics, will have their word in the matter, and claim their place in the large domain called "science."

It is, perhaps, time to call a halt; and after laughing at "high *priori*" roads to science, to consider more seriously whether or not those same *a priori* methods have not some place even in the study of nature, whether or not the analysis of reason's fundamental concepts and necessary judgments is absolutely worthless for scientific ends.

Admitting, provisionally, the absurdities of Aristotle and his school, cheerfully granting the necessity of verification of all deductive inferences, yet I have reason to maintain that that *a priori* road, where every concept is rigidly defined, and primary truths are analyzed, truths absolutely unassailable, has proved suggestive of observations, fruitful in inferences which might have been verified, but which have been very slowly reached, and only as hypotheses, by the empirical route.* The inquiry, it seems to me, is not unpromising; the result may appear in a re-examination of Aristotle's Physike Akroasis.

At a first glance, one is impressed by the glaring difference between this treatise and modern works bearing similar titles. It is not merely that Aristotle cites some observations, so-called, which were reported to him, or which he himself noted with very inaccurate observation; for the same thing has happened since his time. Thus one of our chief contemporary authorities in natural science, cites certain facts, so-called, which were privately confessed to me, many years ago, to be sheer imposture, and are now publicly so acknowledged. (M. & K. Fox.)

But, setting this aside, one sees in a modern treatise the attempt, at least, to follow a strictly empirical method, and to attain higher and higher generalizations by careful inductions. In the Physike Akroasis the aim is to clear up those primary concepts which underlie all physical investigations, and to make strict logical deduction from certain primary principles, however those may have been obtained, which have the most absolute and intuitive certainty.

This difference is of course largely due to the fact that Aristotle is aiming at the philosophy of physics; to secure clear concepts and precise definitions, to determine (I. 1,) the principles, causes and elements concerned in nature.

Aristotle first (I. 1) indicates his method, which is to proceed from what is more familiar as coming under the observation of the senses, to what is more fundamental, to elements, causes and principles. I suppose that we must not call this " Baconian induction," but rather analysis. That which is primarily given to us in knowledge is complex; we analyze it, using also logical induction in order to reach remoter, but higher principles. Verification would of course supplement this method, but our author makes very imperfect use of that.

Physics, in its widest sense, embraces all the sciences of nature. What

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Grove, in the preface to his " Correlation, etc.," claims what is expressed by his title as the latest and grandest discovery in physics. We will not dispute his assertion, if he means experimental physics. But inasmuch as Aristotle maintains that all change in nature (and nature is that world of beings whose characteristic mark is change, II, 1; III. 1,) is reducible to local motion, and gives clear demonstration of his proposition, Grove's assertion, taken in its widest sense, seems hardly warranted by the facts. On the contrary, the *a priori* method ought to have pointed out, in this case as in others, the road for experiment, by giving anticipations from something more than "scientific imagination" of the results which might be expected.

is nature? A collective name for those things, together with their causes, etc., which have in themselves a principle of motion or change (kinesis). (II. 1.) It is necessary, then, to have clear concepts of matter, form, cause, change, including local motion, time and place or space, with their correlated ideas, and this is the aim of the treatise now before us.

(I. 6, 7). Two principles at least, perhaps three, are necessary to explain nature as it is known by us, viz., a passive matter, and an active force, manifested in contrary phenomena; (attraction and repulsion, heat and cold, etc.)

Motion, kinesis, taken in the widest sense, is the (continuous) transition from a potential state to an actual state. It is either a change of quantity, or of quality, or of place. But the three are reducible to one, viz., local motion. (VIII, 1.) If to these we add the change from potential to actual being in generation, and its contrary, decay (phthora) we shall have the whole sphere of changes perceived in nature.

II. 2. Applied mathematics consider the purely intelligible and unchangeable element which is found in nature, underlying all its changes.

II. 3. We accouut for any of those changes which we perceive in nature, when we assign their causes. But the word cause is very ambiguous, and needs definition. All uses of the word are reducible to four: (1). The *material* of the thing which comes into being may be called its cause, (condition), as marble of the statue; (2). The *form* or pattern, as the idea of an oak is that towards which the acorn develops; (3). The efficient cause or originator of the change which may itself be a changeable antecedent; (4). The *end*, or final cause, or reason why. Why does one take exercise? The cause is not fully given, if we name the man, describe the exercise and account for muscular contraction; we add (II, 3), another cause; sc., the exercise is for the sake of health.

In discussing cause, also, we must not overlook the fact (II, 7) that two very different principles are requisite in explaining nature, sc., the sensible antecedents, and the intelligible principle which is not physical nor subject to change. Nature requires for its explication the supernatural.

II. 8. The discussion of final causes is of such interest in connection with modern physics, and especially with reference to recent questions in Natural history, that I may perhaps be allowed to present it in condensed paraphrase. Why would it not be sufficient explanation of the expansion of water cooled down to 40 degrees of Fahrenheit, if we could, as we cannot, assign its physical antecedents? But our mind recognizes a relation to the good of the world, an order and connection of things. And we must assign chance, spontaneous action, or design, in accounting for that order, if we assign any cause for it. (Chance, here, does not mean the entire absence of law, but a law which does not enter into the series of events in question.)

By chance results may be obtained, indeed, as, when our guest came for other reasons but took a bath at our house, we say that by chance he took a bath. But neither chance nor spontaneous action will account for the invariable series in nature's work which I have illustrated in the expansion of cooling water with its effects; therefore, final cause must be assumed. I am not considering the value of this argument; I only note it as the first.

Secondly. each thing in nature acts as it is adapted by nature to act; and as it acts, so it is adapted by nature. It acts for some end, therefore it was naturally produced for that end. If a house were among natural things it would be constituted as it now is by art. And if natural things could be produced by art, it would constitute them and adapt them as they now are. Art sometimes imitates nature; sometimes attempts what nature does not; but in both cases for some end. The argument, then from art's having an end to final cause in nature is valid; for the relation of prior to posterior is the same in both.

Thirdly, we have no warrant for imputing conscious art or deliberation, to insects or to vegetables; yet there is an end, a form towards which these work.

Here we note an objection, that if nature seeks an end, she does not always reach it. But the same thing is true of art, wherein all admit the existence of final cause. This principle does not exclude the principle of necessary conditions, which are found in the matter by which all things that are produced are conditioned. In these we must find the cause of failure. The end of a saw is to cut wood, but iron is the necessary matter, and may be the cause of failure. So nature requires the matter, but the end is found in the form, the idea (eidos). If the end is to be reached, the antecedent conditions must also exist; if these latter do not exist, then the former cannot exist.

Without criticizing these arguments, I note the wide divergence of method from the empirical. But as the latter can only discover antecedent conditions existing in time, we need not allow it to interfere with our estimate of Aristotle's analysis of final cause and his attempted demonstration.

Its value seems to consist largely in its fixing attention on the necessity of a rational explanation of nature. For who explains a watch by merely stating its materials, and the physical antecedents of its motions? The plan, the adaptation of part to part, the end accomplished, are still more essential. So in nature. Who explains a woodpecker's tongue, if he describes its anatomy and mechanism, and speculates concerning its origin, but leaves out its relations to the bird and the conditions of its life?

III. 6. The infinite is a physical concept which requires examination and definition. Physics treat of body, that which has dimensions; and whether it be known sensibly, or regarded in thought, it is necessarily limited, finite. Potentially it exists in thought as indefinite, (apeiron) that from which something can always be taken away, which can be always further divided, to which something of the same kind can always be added. Distinguish, therefore, the perfect, the completed whole, (teleion) which as such, admits of no addition or subtraction.

I pass over the proofs that the universe as a whole is finite in magnitude. In the Fourth Book we find the well known analysis of place as a relation existing between corporeal things, the relation of some actual finite body to its container. The universe, as a whole is therefore not in place. (III. 5.)

IV. 8. What then, do we mean by space? It is merely the indefinite (apeiron) enlargement of the same idea, applied to the potential, not actual, extension of bodies with their three dimensions. In other words, space is no actualized entity, but the indefinite thought whose actuality is *place* as a relation in actual bodies. I do not see that in this we have made any advance from our author. Physical science can tell us whether we need anything more.

IV. 8. Aristotle clearly sees and points out the relations of the problem of the existence of a *vacuum* to this question of space, and denies its existence. Vacuum is unintelligible, it involves contradiction in thought; it contradicts experience.

From this denial of a vacuum follows a mechanical theory of motion, (kinesis) which Aristotle intimates, but does not follow out, neither was any man then competent to do so.

IV. 10. Motion and time are co-eval. There never was a time in which motion did not exist. Which brings us to a physical conception, as fundamental as it is thoroughly established, and I believe, as fruitful as any in Aristotle's physics. What is time? He proves that it is not an independent entity. It is not change, which is particular, found in this or that.

IV. 10. It is not motion, which is faster or slower; predicates which are not applicable to time. And yet it requires motion; i. e., change; and all things which are immoveable, unchangeable, are not in time. Time is continuous; it is limited by what we call "now;" which is like a moving point describing a line.

So we reach our definition; "Time is the number of motion (change) in respect of prior and posterior." This, of course, implies an intelligence to do the numbering. In a purely material universe there would be no such thing as time. (It may seem to us otherwise; but we put ourselves there to do the numbering.)

IV. 11. Time is continuous, not an aggregate of instants or nows.

IV. 12. A very plain deduction is that time is either finite, actually, or indefinite, potentially. But it can never be perfect (teleion) or what I should call the proper infinite. When limited by two nows, like two points, e. g., one past and the other that moving point which we call the present, time is finite; disregarding either of the nows, we get the potentially infinite (apeiron) in duration.

IV. 12. Things which are not in time (and such things there are), neither move nor rest. For rest is the privation of motion, and is numerable in the same way. Those beings only are in time which are subject to motion, to change.

IV. 14. Is time such a relation that it would not exist if there were no mind to number continuous change and refer it to some measure? That seems to be necessary deduction from our definition of time.

VI. 1. Time, like every other continuous quantity, cannot consist of indivisible units, any more than a line can consist of successive points.

VI. 6. All changes, like time their number, are, potentially, divisible *ad infinitum*. From this is deduced the very suggestive principle, that no change or motion can possibly be instantaneous.

In Aristotle's De Sens, Chapt. VI, he applies this principle to show the progressive motion of light.

VII. 1. Wherever there is change, or motion, there must be an antecedent, efficient cause, which itself may be something moved or changed. And so we may make a regress indefinitely; but such a series cannot be infinite.

I do not propose to follow the metaphysical proof of this proposition, but only to note the result, viz., that in physics a first moving cause which is not itself subject to change must, according to principles of reason, be assumed to exist. We shall not reach that first cause, perhaps, by regress through the chain of changes; for these are discovered by the senses; but this first cause is not so discoverable, but is an intelligible principle, necessary in accounting for change, and known with absolute certainty to exist.

VIII. 1. Motion, change, cannot be annihilated. Nature is orderly, subject to law, and the law of continuity of force carries on successive changes in the indefinite extension of time.

VIII. 5. Let us consider further the prime mover. It may indeed, act hrough many media, just as a man may impel a stone through the media of his cane, his hand, etc.; but it is impossible to recede in such a chain through an absolute infinity of links. The first mover, then, is self-moved. It does not constitute one of the chain of links; for those are sensible, the prime mover is purely intelligible. It is itself immutable. Everything which is mutable, is also divisible. But the prime mover is one and indivisible.

VIII. 6. It never changes, but the things which are moved change their relations to it, as it does to them. Here I observe, in passing, that the changed relations of Deity to the world of finite beings, according to this principle, are based on changes in the things which belong to time.

This prime mover is eternal. For motion has neither beginning nor end. It has absolute unity. There may, indeed, be many motors which are immutable; but if they come into being, or cease to be, there must be a cause of that, as of any other change. Thus, we are carried back again to the eternal, primal mover. All change is, in ultimate analysis, reducible to one continuous motion. Therefore the first cause is one only. All living things may be called self-moved; but they are also changeable and conditioned by external things.

Concluding this too brief review of Aristotle's fundamental physical principles, I will try to state what laws of nature now empirically established, he rationally deduces from first principles of reason, by aid of his accurately defined concepts.

1. All change is reducible to local motion.
2. Energy is an unchangeable quantum, enduring through all transmutations. Motion is never destroyed.
3. All indefinitely continuous motion (local) is in curved lines.
4. Light, and, by parity of reasoning, all changes of condition in matter, transmitted through space, are not instantaneous, but require time for their transmission.

THE DEFECTIVE CLASSES.

By A. O. WRIGHT,

Secretary of the State Board of Charities and Reform.

The defective classes form a series of small but very troublesome tumors upon the body politic. For various reasons, ranging all the way from the imperative need of protection to society up to those humane influences for which our century is distinguished, these classes have fallen under the more or less effective guardianship of government in all civilized countries. Private effort is also doing much to palliate or to prevent the evils which the defective classes bring on themselves and upon society at large. And still there is everywhere an apparent, if not a real increase in the number of these classes and in their ratio to the total population. It is claimed that this increase is in many cases caused by the very efforts which are made to care for them, and it is at least certain that these efforts bring to light many cases of evil which would have been hidden, and preserve many miserable lives which would have been allowed to perish in former days. In other cases it is claimed that the complex conditions of modern society favor the increase of these classes. At any rate the subject deserves attention and study by the philanthrophist as well as by the statesman, by the student as well as by the man of affairs.

It seems to me that the following classification of the defective classes, which is original with me, is more philosophical than any other I have seen and also as good for practical purposes as any other. This classification depends upon the three divisions of the mental faculties which are generally accepted by psychologists. Insanity and idiocy are different forms of defective intellect. Crime and vice are caused by defect of the emotions or passions. And pauperism is caused by defect of the will. Blindness and deafmutism are defects of the senses requiring special forms of education, but are not defects of the mind any more than the loss of an arm or a leg. Blind or deaf and dumb people properly educated are not a burden or a danger to society as are criminals, insane persons or paupers, Their defects are physical not mental, and they should not be classed with persons who have these mental defects.

The above classification has the advantage of starting from the center instead of from the circumference. "The mind is the measure of the man" and it is the abnormal and defective mind which produces the mischief rather than the physical disability or the social conditions. Doubtless these have their influence, but it is a more remote influence. The immediate cause is in the mind, and the cure, if there is to be a cure, must be addressed to the mind either directly by argument and influence or indirectly by changing the conditions surrounding the subject, so as to change his motives. Anything which fosters abnormal and ill-regulated thoughts or passions or which weakens the control of reason, conscience and will over the mind tends to produce insanity, crime and pauperism. Everything which aids self-control reduces the tendency to these abnormalities.

I am speaking now of these classes as a whole and not here taking account of the exceptions to be found in them. I know a man who was a good average man in every respect, but who by a fall upon his head from a load of hay, was made insane, deaf and dumb and blind, all at once, and who is still thus triply afflicted, but is otherwise healthy. In his case the insanity was a pure accident. The state of Georgia severely punished the missionaries who undertook to civilize and christianize the Cherokee Indians contrary to the laws of the commonwealth. They were criminals in one sense, as violators of human law, but no one will attempt to class them as criminal in anything more than a technical sense. I once found an old man of good character and standing in the community in a poorhouse. He had given his farm to his son on condition of his son's caring for him in his old age. The father was tortured with chronic rheumatism and was therefore some trouble to care for. The son sold the farm and moved out of the state, leaving his poor crippled old father to die in the poorhouse. The father was an accidental pauper and could not fairly be included in the list of voluntary paupers. But such cases as these are exceptions, and the rule is as I have stated it.

The distribution of the defective classes by nationality, education, wealth, age, sex, occupation and the like, is interesting from a scientific point of view and important from a practical standpoint. A study of the distribution of insanity, crime and pauperism, may reveal the conditions which create or foster them. And as society has more or less control over social conditions, it may become possible to heal some of these ulcers on the body politic, if we know where they are and what irritant produced them. But please notice that I say may, not shall. The small success of all effort in the past toward curing these evils, ought to make social reformers modest.

First the question of sex. Men and women are about equally afflicted with insanity. Massachusetts has more women than men insane, because it has more women than men in the total population. Wisconsin has more men insane than women, because we have a preponderance of the male sex. Either the causes are the same in men and women, which produce insanity, or they are equivalent. Heredity, worry, over-work, under feeding, sickness and the weaknesses of old age affect women and men equally, and the perils of childbirth and of loneliness for solitary farmers' wives are about equal to the dangers from accident and the vices to which men are exposed.

But crime and pauperism are liabilities of men much more than of women. There are generally about forty times as many men as women in our state's prison and in our jails and houses of correction. The disproportion is not quite so great in some other states and is still less in European countries. In Europe there is no sentimental pity for a woman on account of her sex. In this state a few years ago, a farmer was murdered by his wife and the hired man. The hired man is now in state's prison, while the more guilty woman is free. But even in Europe the proportion of men to women is perhaps ten to one. Women do not commit crime as readily as men do; it may be from principle; it may be from cowardice; it may be from lack of temptation.

And women do not become paupers as readily as men. In getting outdoor relief, it is true, women are a little ahead of men, but that is because it is easier for a woman to get poor relief than for a man. And in fact, where outdoor relief is laxly administered, though it is the women who usually apply for it, there are often lazy men behind them sending them for it or else drinking up all their earnings in the comfortable consciousness that the public will support their families. One case I heard of in this state, where a man spent all his week's wages every Saturday night and Sunday, at a certain saloon, whose proprietor was the officer who gave public money to support the wife and family. That man was the real pauper, not his wife. So that even in outdoor relief, it is probable that the men have a good share of the pauperism. And in the poorhouse, as I said, there are thrice as many men as women.

Second, as to age. About an equal number of each sex are born idiots and remain so all their lives, so that the question of age in idiocy need not be taken into account, except that idiots are not long lived. But insanity is a defect of mature years. Out of thousands of insane whom I have seen, I only remember two insane children. Going through an insane asylum, you are struck with the general age of the patients in contrast with the youth of the attendants. This, of course, is partly caused by the fact that insanity is not very curable. Only about one-fourth of the insane recover, a few die, and the rest end their days as chronic insane. But it is also caused by the fact that most insane are middle aged, or elderly before they become insane.

Crime is rarely committed by little children, and when committed, is excused by the law or by the judges and jury. The absurdity of hanging a boy for murder or sending him to state's prison for life for burglary, both of which have been actually done in the south recently, is not allowed in any northern state. But every visitor to a jail or state prison must notice the comparative youthfulness of the prisoners. The average age of the convicts in state's prison is 27. Or, to put it in another way, the majority of convicts in state's prison are under 25. The difference between 27 and 25 is accounted for by the difference between an average and a majority.

The direct opposite of this is the case with pauperism. The majority of paupers are over 50 years old. Criminals are mostly young men. Paupers are mostly old men and old women. Youth is the age of passion, and perverted passions lead to crime. The author of the Jukes Family, the best sociological study ever made, says that among the descendants of Margaret, the "mother of criminals," it is very noticeable that in youth they were prostitutes and criminals, and in age, beggars and paupers. The same perverted instincts which led them to prey upon the community, took the direction of crime in the time of strength and of pauperism in the time of weakness.

The question of tramps comes in here. A tramp is a person determined to live without work, and who therefore is compelled to wander from place to place in order to do so. No individual, or society, or institution, or community, will support an able-bodied loafer in idleness any length of time. But many will give a little money or bread out of mistaken sympathy to a stranger, or as the easiest way to get rid of an annoyance. I have seen some thousand tramps, and with very few exceptions they were young men, I have seen two or three men fifty or sixty years old, and I have seen two or three women tramps. But I have seen hundreds of young men under twenty-one, and thousands under thirty, healthy able-bodied men. Among them were a few who were ready for robbery, burglary or rape, if a good opportunity offered. And in the judgment of skilled officers, there are some murderers and other criminals hiding among the tramps. But the mass of the tramps prefer to prey on society by beggary, rather than by crime. If they were bolder they would be criminals. What becomes of the old tramps? I do not believe that many of them live to be old. They are killed on the railroads or die of exposure. Many of them tire of tramping and get back to work again. Some drop into crime and get into prison, and are in some cases reformed by the steady discipline of prison life. One tramp told me that he got the opium habit through the toothache, and was broken of it by being sent to state prison for burglary. Other tramps break down and die in poor houses or insane asylums. We probably have a hundred tramps in our insane asylums in this state, and about as many in our poor houses. This is an enormous proportion to be furnished by from 500 to 1,000 tramps, the probable number who are in our state at any given time.

The question of education is often stated as if education favored insanity and opposed crime and pauperism. As a fact, I do not think that education has so great an influence either way, as many seem to think. We were told half a century ago that it was cheaper to build school houses than jails and poorhouses. We have dotted the country over with schoolhouses, and we find that jails and poorhouses are just as necessary as ever. But some one may say that this is because there is no effective compulsory education and because we have an unusual number of ignorant foreigners coming to our shores. But this is sufficiently answered by looking at Germany, with its homogeneous population and compulsory education and compulsory religious, as well as secular education, at that. In Germany, crime and pauperism and insanity are increasing as they are with us. Criminals, paupers and insane, all average a little below the rest of the community in education. There are, of course, exceptions. In the case of the insane and of criminals we can all of us point to conspicuous exceptions. I know a few cases of educated paupers, but very few, because their relations or friends care for them and do not let them go to the poorhouse. Inspecting a poorhouse a while ago I found in one of the rooms a book which had been given as a prize for scholarship in a famous New England academy. The owner had been district attorney of the county, and was now in the poorhouse through liquor. All efforts to reform him had proved in vain. But the fact remains that the average of the defective classes is of a lower intellectual grade than the average of the community. Their smaller knowledge and less natural ability makes them break down into insanity more easily and easier drift into crime or pauperism.

The best statistics of criminals have been kept for over half a century by the Eastern Pennsylvania penitentiary. The results of these statistics seem to show that idleness rather than ignorance is the mother of crime. An investigation, which I made a few years ago by personal inquiries from poorhouse to poorhouse in Wisconsin satisfied me that about one-third of the paupers are made so by idleness, one-third by liquor and one-third by all other causes combined. In my judgment the idleness which makes truants from school and therefore poor scholars, leads to crime or pauperism in many cases, and in those cases it is not ignorance which is the cause of crime, but idleness which is the cause of both ignorance and crime.

The question of social standing is not of as great importance in this democratic country as in Europe. Paupers of course do not come from the wealthy or the middle classes. Many of the laboring classes do drop into pauperism through misfortune or vice. But many of the paupers are not even of the laboring class, but come from the outcasts of society. The same is the case with the criminals. They do not come very largely from the wealthy or middle classes. Some of them come from the laboring classes, but they are very largely from the outcasts of society. To some extent this holds good with insanity, but only to a small degree. The insane are found in all classes in considerable numbers, but the laboring class furnishes more than its share of insane, and the outcasts an immense proportion to their total number. Criminals and paupers frequently become insane, I should say, ten times as many as from the same number of average humanity.

The advantages and disadvantages of city life have often been talked of.

Many people suppose that the excitement and strain of city life conduces to insanity. Others say that the loneliness of country life has the same effect. An English physician has taken the pains to tabulate the statistics of insanity for the city of London for forty years and for several purely agricultural counties in the south of England with about the same population for the same period of time, and finds that there is no difference between city and country in the amount of insanity. But for crime, all statistics show clearly that crime is concentrated in the cities, which are the refuge of the criminal classes and the nurseries of young criminals in the neglected street children. Pauperism is greater in the city than in the country, though this may arise from the corrupt municipal governments encouraging pauperism to win votes.

Now I come to some very curious results of the United States of 1880. According to the figures of the census, insanity is about twice as prevalent among foreigners as among native whites, and about twice as prevalent among native whites as among negroes. In round numbers one in a thousand of the negroes of the United States are insane, one in five hundred of the native whites, and one in two hundred and fifty of the foreigners. There has been a great deal of nonsense written upon this by learned men about foreign governments shipping their insane to us to take care of. The fact is that the ordinary immigrants are healthy young people, with less insanity than the average, and that comparatively few cases of insanity are shipped over here, and that in recent years a strict watch is kept at the ports against the shipment of any of the defective classes to this country. One observation will prick this bubble. In the census the children of foreigners born here are counted as natives, properly enough; but by taking away from the foreign population most of the children and adding them to the native population, it makes an unfair basis on which to estimate the proportion of insanity, as children do not become insane. The proper basis would be what is the proportion of foreign born insane to the adult foreign population, and of native insane to the adult native population. On this basis there is still a slight disproportion of the foreign and native insane, but not more than can be accounted for by the comparative ignorance and poverty of the mass of the foreigners who come here and the trials they have to meet in adapting themselves to the conditions of life in a strange land. But why are negroes so much less insane than white people? I do not pretend to say. Perhaps it may be on account of their easy, happy dispositions, which makes them less thrifty than the whites, but also less liable to bring themselves into insanity. Dr. Bryce, of the Alabama State hospital, says that insanity since the war is rapidly increasing among the negroes.

There is a greater proportion of crime and pauperism among foreigners than among natives, probably because of their greater ignorance and poverty, and because they have been accustomed to rely upon a paternal government and do not get accustomed to the freedom of America. The greater tendencies to pauperism I ascribe to the fact that in most European countries the laboring class is on the verge of pauperism and is continually being pushed over into it by sickness or old age. In England two per cent. of the population are paupers and a large part of the agricultural laborers end their days in the workhouse, for the reason that they barely get a living when able to work and therefore cannot save anything for old age. The paupers in this country are a great deal less than half of one per cent. of the population. Where the laboring classes are brought up to expect to end their days in the poorhouse, it is not wonderful that in coming to this country they seek relief easier than the natives do.

Negroes furnish a larger proportion of crime and a smaller proportion of pauperism than the waites. As the negroes are mostly massed in the southern states, we may look at the condition of society there for part of the explanation of this. Negroes get little sympathy from whites in the south and consequently do not easily get into poorhouses, but do easily get into prison. Negroes do not consider petty theiving very wrong, having learned that during slavery times. A negro will not starve as long as there are smoke houses and chicken coops in the neighborhood, and the climate does not require much in the way of houses, clothing or fuel. But the penitentiaries are filled with chicken thieves. Alabama has three large penitentiaries and Wisconsin one small one, the population being nearly the same.

The effects of climate have not been much considered. But I believe it will be found that warm climates do not have so great a proportion of insanity as cold climates. It is certain that in Europe, Greece has a much less proportion of insanity than Norway. In this country there is less insanity in the south than in the north in proportion to population. A part of this is due to the negroes in the south having a small proportion of insanity, and the foreigners in the north having a large proportion. But it is possible that climate has also something to do with it. I cannot discover that climate has anything to do with crime. Pauperism is increased in cold climates by the greater difficulty of getting a bare subsistence.

Much has been said about the rapid increase of the defective classes, especially of the insane. Statistics show this both in Europe and America. But statistics of the mere numbers of insane at any given time are very deceptive. The greater humanity with which the insane are treated now than a hundred or even twenty-five years ago has preserved their lives and thereby caused an accumulation of the insane. This greatly increases the numbers who are alive at any given time, but does not show that any more persons become insane in any one year than ever. Careful statistics have been kept in England with reference to the latter point and it is found that there was an increase in the proportion of commitments to the total population up to a recent time, but that it now seems to have reached its highest point and become stationary. It is believed that the increase in the commitments was caused partly by the discovery and placing in institutions of cases that would otherwise have been hidden at home and partly by calling things insanity which formerly would have been called by some other name — such as senile dementia, epilepsy eccentricity or primary dementia. I believe that these statistics show that insanity is not now increasing faster in England than the population.

In the United States insanity is obviously increasing very rapidly. In ten years in Wisconsin the insane under public care have increased from about 1,700 to about 3,000. This is partly due to the causes discussed above. But it is also due to another fact, to which I was the first to call attention, now generally accepted, that the ratio of insanity to the population is much greater in the older states than in the newer ones and in the older counties of Wisconsin than in the newer ones.

In 1860 there were only 200 or 300 insane in the state. In 1880 there were 2,200 including those at home. And now there are probably 3,300 including those at home. The pioneers of Wisconsin were healthy young people, who left their insane behind them. It has taken two generations to reach the amount of insanity we now have. But if we had the proportion of insanity to the population which Massachusetts now has, we should have nearly twice the number of insane we now have. We may expect to keep on with our increase till we reach the proportion of Massachusetts and of England. Already some of the older counties in Wisconsin are approaching that proportion, while those in the north have only the ratio of our far western states and territories.

The rapid increase of crime in this country is doubtless an incident of the rapid growth of city population. But probably the more careful administration of the laws has increased the number of prisoners, while the system of reformatories for boys and girls and all the good influences of christian civilization have been resisting the increase of crime. It is noteworthy that a better prison system in England than we have in this country, joined to the private reformatory work of all kinds, has brought the increase of crime to a stop, and that there is absolutely less crime in Great Britain now than there was fifteen years ago notwithstanding the increase of population.

It is fair to call attention to the fact that the only reliable statistics of crime are from the state prisons, partly for the reason that jails and police stations do not always keep accurate registers, and for the more important reason that officers make petty crimes appear to be less or more at their pleasure. For the sake of fees or to get a reputation for efficiency officers and magistrates often largely swell the number of prisoners by "running in" tramps and drunks to suit their own notions.

The same causes have made an increase of pauperism in this country — the growth of cities and the foolish or corrupt use of public money in aiding undeserving applicants for poor relief.

To a considerable extent these three defective classes link into one another. It is hard to say whether a tramp is a pauper or a criminal.

Many criminals may be called insane and some are when they have money or friends to help them, and some insane have criminal tendencies. A very large per cent. of criminals become insane in prison or afterward. A considerable number of paupers become insane. The children of the one class pass easily into the other class. Street children who are the children of misfortune are easily drawn into crime. Here and there in our country, and in every other one are knots of defective classes all tangled up together, families closely related furnishing a whole population of criminals, paupers, idiots and lunatics among themselves. Such were the family in Ulster county, N. Y., called by Dr. Dugdale the Jukes family to disguise their real name. Such is the "Tribe of Ishmael" recently described by Rev. O. C. McCulloch in Indianapolis. The interchangeability of these defects is very clearly shown in these cases. Another noteworthy thing is the general physical weakness of these hereditary defectives, running easily into consumption and similar diseases. Even in good families with a hereditary taint of insanity it is noticable that it is interchangeable with consumption. One generation or one brother or sister has consumption, another has insanity. Or the same person has insanity but recovers of insanity to die of consumption.

What are we now doing with the defective classes. With some exceptions all civilized nations are pursuing the following lines of policy. Pauperism is relieved and discouraged. The treatment fluctuates between the extremes of lavish relief and stringent discouragement, but is generally a compromise between these two extremes. Insanity is cured if possible, if not, it is usually protected in institutions of some sort. Crime is punished in prisons and prevented in reformatories. These methods express the average wisdom of the present generation, which is far in advance of what has previously been done for the defective classes. It does not follow that this is the best that can possibly be done for them. In fact here and there experiments are in progress which I believe represent not the average wisdom but the best wisdom of our times. Here and there private societies have taken up the work of eradicating pauperism, not by relief, which often encourages it, nor by merely repressive measures, but by carrying out the motto of the charity organization societies, "Not alms, but a friend." And Rev. J. H. Crooker, of Madison, has recently shown by a remarkable historical investigation that this is not a new discovery, but is a century old, when it was more fully applied to public poor relief than it has since been. The methods of reforming criminals and these of reducing crime have been discovered and applied in the British Isles, while in America they have been only so applied in a few places. The methods of treating the insane have been growing milder and more humane in Europe and America within a few years. In my judgment the State Hospital of Alabama and the county asylums for the chronic insane of Wisconsin, mark the highest point yet reached in the direction of liberty for the insane. At the rate of progress which we are now making, it will take a generation for the average American treatment of the defective classes to reach the standard set for pauperism by the charity organization societies, for crime by Elmira and Concord, and for insanity by the Wisconsin system of care for the chronic insane.

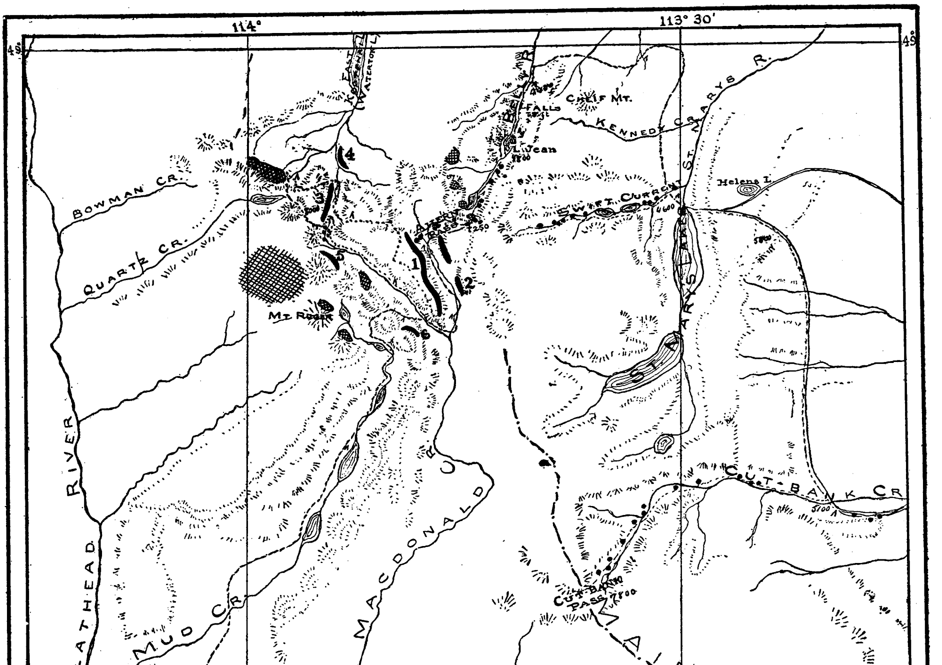
Our measures of treatment of the defective classes sometimes increase the very evil we meant to cure. Poor relief, instead of relieving pauperism, very often increases it. Insane asylums seem to increase the number of insane, prisons of criminals. This, however, is not a necessity of the cure, but only an incidental evil, which needs to be guarded against. We must also allow that our humane methods of treatment, in addition to the good effects which they have, do also tend to increase the number of defective classes, by prolonging their lives and by making their lot a more desirable one. I have already mentioned the accumulation of insanity by the mere prolongation of life in the insane in civilized countries. It is still a question whether this does not sufficiently account for the greater number of insane in civilized over savage countries.

Where the insane are killed as witches or executed as criminals or killed by private vengeance or malice or allowed to die by neglect, and where only the robust can survive the hardships and perils of life in any case, it is not wonderful that the insane existing at any given time are few. So also with pauperism. If no poor relief is given there will be no paupers, for some will starve and others will steal. But crime seems to decrease with milder punishment, whether these are the cause of the decrease or only a result of the general civilization of society which is reducing both crime and punishments alike. It is also true that we discover and do something from a large number of cases now who would not be known as defectives under a less perfect administration of government. This is one of the causes of the increase of insanity, as I have already said. Crime is more completely looked after and things are called crime now which would not have been called so a few years ago.

But on the whole I believe that the measures we are taking to treat the defective classes are really reducing the numbers. For one thing, we keep them shut up in institutions, where they are not allowed to propagate their kind, or to practice or teach their vices. A notable exception to this is the county jail system, where prisoners are herded together in idleness to constitute schools of crime and vice. Our methods do also cure many of the defectives. About one-fourth of the insane are permanently cured. From half to two-thirds of the criminals are never convicted a second time. Many paupers and tramps do finally drop back into society again. It is of course a struggle which may be made to appear to be tending one way or the other according as we are optimistic or pessimistic in the best of our own minds. But I take the side of the optimist and believe that we are gradually healing up these ulcers upon society.

The best sign of the future is that public sentiment and legislation is steadily tending in the direction of prevention as well as of cure. Some measures of prevention like the various phases of child-saving work have been already fruitful of good results. In other cases it is still doubtful what is best to be done in the way of prevention. But I believe the time is coming, when by the combination of public and of private effort we shall greatly reduce, if we do not entirely eradicate the defective classes.

In my dealings with them I am sometimes tempted to despair of humanity. But then I look at our churches and schools, our literature and our industries, and best of all our happy homes, the pledge of the future; and I take heart again, and I remember that after all the total number of prisoners, paupers, insane, deaf and dumb, blind and idiots in the United States is only one per cent. of the population, a less proportion than any other civilized country has.



Map of a portion of Northwestern Montana, slightly modified, and reduced from a map made in September, 1891, by Lieut. Geo. P. Ahern, of the 25th United States Infantry. Scale: One inch equals ten miles.

NOTES ON A LITTLE KNOWN REGION IN NORTHWESTERN MONTANA.

BY G. E. CULVER.*

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* The petrographical notes included in this paper were kindly furnished by Dr. William H. Hobbs, of the University of Wisconsin, to whom the writer wishes to make grateful acknowledgment for this and other favors.

INTRODUCTORY.

The party.—In August, 1890, a small party of soldiers under the command of Lieut. George P. Ahern, of the Twenty-fifth infantry, was sent to explore the mountainous region in northwestern Montana. The party as finally made up consisted of two mountaineers, packer and guide respectively, two prospectors eager to take advantage of a new route to possible gold fields, two Indian guides, a squad of soldiers, black as ebony, the commanding officer, and the writer. All were mounted and well armed. Thirty days' rations were carried. It was supposed we would reach an outpost on the west side of the range in a month, to which point another thirty day's supply was sent. Owing to the assistance of various hungry natives and the keenness of mountain appetites our rations lasted but twenty days. Game of all kind was abundant, but the noise made by the passage of such a party prevented very frequent additions to our larder from this source. A few ducks, grouse, and ptarmigan paid our "cook-house" a visit, as did numerous fine trout. Of large game we secured one bighorn, and sixteen mountain goats. The young of the latter are very fine eating; the old bucks taste of musk.

The region covered by the route lies between the 49th parallel on the north and the 47th on the south, and between 112° 30′ and 114° 30′ west. It is divided naturally into the following regions: 1. The western border of the plains, a strip 40 by 130 miles. 2. The narrow belt of foothills, four to twenty miles wide skirting the range. 3. The main range of the Rocky mountains, and 4. The Great Flathead valley with its tributaries. In the eastern portion of this region, well toward the national boundary, the Piegan and Blackfeet Indian reservations are located. In the southwestern portion is the Flathead Indian reservation, extending from Flathead lake down to the Northern Pacific railroad. With the exception of these agencies lying on the outer border of the region it is wholly uninhabited, and, so far as could be learned, almost wholly unexplored.

Object of the journey.—The object of the expedition was to find, if possible, a pass over the main range farther north than any then known, to map the course of the streams and the principal Indian trails. As such a trip might offer some opportunity for geological observation I accepted Lieut. Ahern's invitation to join him.

Region traversed.—We left Fort Shaw, Montana, on the morning of August 5th. Our route for the first ninty miles was over a rolling prairie, somwhat west of north, but gradually swinging more to the west, until at the end of the fourth day we went into camp in the foot-hills close up to the base of the main range on the Cut Bank Creek, thirty-five miles from the boundary. A fairly good wagon trail leads to this point, and our supplies had been so far transported by wagon. They were now transferred to the pack-mules, who entered a vigorous protest against this return to more primitive methods.

Our course from the Cut Bank was nearly north to the national boundary, which we touched first in longitude 113° 30′ west. From this point we moved westerly to the valley of the Belly River, crossing the main range at the head of that stream about fifteen miles south of the boundary, in longitude 113° 40′. From the new pass we descended by the way of Mud Creek into the valley of the North Fork of Flathead river, our course being very crooked, but averaging about southwest by south. Our farthest west, 114° 45′, was reached near the 48th parallel, at which point I left the party, returning home by the way of Flathead lake and south to the Northern Pacific railroad. We were eight days on the plains and twenty-two days in the mountains. Side trips were made as follows: Up the Cut Bank to the summit of the main range, where there is an easy pass at an elevation of 7,800 feet; up the Swift Current from the foot of St. Mary's lakes also to the summit, but a vertical descent on the western side, of many hundred feet barred further progress there. Another trip was made over the divide between MacDonald's Creek and the head waters of the East Kootanie to Glacier Creek. Tho whole distance traveled in saddle or on foot was estimated at 370 miles.

PREVIOUS EXPLORATIONS.

So far as I know, the only explorations in this region previous to our visit were by members of the Boundary Commission along the 49th parallel, and by Dawson, McConnell, and others of the Canadian Survey on the north side of the line. None of these, so far as I can find, traveled far south from the line in the mountains.

GEOGRAPHY AND GENERAL DESCRIPTION.

The plains.—The region lying east of the mountains from Fort Shaw to the boundary is a high prairie, sloping rapidly from west to east and traversed by occasional swift streams from the mountains. The elevations range from 5,000 feet at the base of the mountains to 3,500 at a distance of forty miles east. The Milk River Ridge, where we crossed it, rises several hundred feet above the streams that unite to form the South Fork of Milk River and over a thousand feet above the surface of St. Mary's Lake. This ridge has a nearly north and south trend near the boundary, but bears a little west of south and joins the main range on the upper waters of the Cut Bank. It is the water-shed between the Hudson Bay basin and the Gulf of Mexico. It was followed by Lieut. Ahern and myself to its junction with the main divide of the Rocky Mountains, and the separation was found to be so sharp that from the summit on the north side of the pass one might without moving from his tracks cast three snow-balls so that one would fall on the Pacific slope, another on the Gulf slope, and a third on that of Hudson's Bay.

The foot-hills.— The high prairie is separated from the mountains by a narrow belt, consisting of a somewhat confused mass of ridges and hills. The ridges constituting the foot hills run in all directions, but the highest are approximately at right angles to the trend of the mountains. The strata are considerably disturbed being usually tilted more, and much more irregularly than the beds in the adjacent mountains. The elevation of these hills is usually under 1,000 feet above the plains, but sometimes runs up to 1,500 feet or more. The line separating the foot-hills from the mountains is quite as sharply drawn in this region as that between the plains and the foot-hills. The latter are usually wooded and somewhat rounded. The mountains, on the other hand, present a frowning battlement of bare and almost vertical walls facing the plain and rising 3,000 to 4,000 above it.

The mountains.— On entering the mountains by way of the valley of the Belly River we found that the range makes makes a sharp bend to the west about twenty miles from the boundary, so that, although we were now traveling nearly south, we were approaching the main divide nearly at right angles to it. The valley is over a mile wide near the boundary, but a short distance up the stream it becomes quite canyon-like. The walls are very steep and rarely less than 2,000 feet high. We went into camp just at the lower end of the canyon, in a dense fog which shut out from view all objects a hundred yards away. In the morning when we looked out of our tents the fog was slowly drifting away and glimpses of the lofty peaks could be had through rifts in the fog. The effect was quite striking. The foot of the mountains was entirely concealed, but at our camp some two miles away the air was clear. Now and then a projecting portion of a mountain side perhaps 2,000 feet above us would be clearly revealed, while above and below the white fleecy veil hid all and seemed to have taken the mountain up bodily and to be about to remove it from our pathway. In other places the upper peaks alone rose clear and distinct above the sea of cloud and seemingly almost over our heads. Altogether it was a picture long to be remembered by those who saw it.

Scenery.— The scenery even along the foot-hills is strikingly beautiful. The lower ridges, rounded and tree-covered, rise abruptly from the plains, while as a background the bare rocky walls of the mountains cut by transverse valleys rise in stately grandeur. A single glance takes in a view of level plain, tumbled foot-hills, and lofty mountains, the latter softened somewhat in their outline by distance. As the summit of the main range is neared plains and foot-hills disappear and the landscape is made up only of rocky mountains lifting their jagged summits above deep narrow valleys down which swift torrents, from the snow-fields and small glaciers above, roar and tumble over their rocky beds, or plunge from ledge to ledge in beautiful cataracts. At intervals in these valleys the falling debris from the canyon walls has dammed the stream and beautiful lakes are formed. The river we ascended takes its rise in one of these lakes, lying in a beautiful amphitheatre at the very foot of the continental divide. The lake is about two miles long and a mile wide. It is supplied wholly by three small glaciers which cling to the side of the mountain 2,000 feet above it. The amphitheatre contains about eight square miles. It is the result of a loop-like bend in the dividing ridge. Its walls are almost vertical, save one portion on the southeast side, and are from 2,000 to 3,500 feet high. The new pass is at the head of this amphitheatre, 7,250 feet above sea.* The dividing ridge itself, the backbone of the continent, is surprisingly narrow and quite sinuous. It is terminated at the summit by a thin wall varying from 50 to 300 feet in thickness and surmounted by pinnacles and chimneys which emphasize its wall-like appearance. It is in many places so narrow and rugged that it would be impossible to travel along it without the use of ropes and ladders. It preserves this peculiar mural character for at least 50 miles.

Ahern Pass.— Ahern Pass is 2,000 feet above the lake at its foot, and the summit wall on either side of the pass was estimated to be at least 1,500 feet more. The entire force had worked two days in making a trail from the foot of the talus slope to the summit of the pass. The assent is very steep and was made with difficulty.†

The Western Slope.— The western slope is in strong contrast with the eastern. A gentle grassy declivity, down which we could indulge in the rare luxury of riding, stretched away for a couple of miles, after which it rapidly became steeper, following the changing dip of the strata, until we were obliged to dismount and lead our horses through the thick tangle of brush with which the steeper slopes were covered. We passed the summit in a biting wind accompanied by rain and sleet, with a temperature of 39°. As we descended the rain increased. We marched in single file through the dripping beech brush, halting every few yards for the

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* It was here that the services of our Indian guide came in play. One of the prospectors with us had three years before camped at this very spot with three other men and had tried for a week to find some means of scaling the rocky wall which barred their way. They were used to the mountains, but were obliged to give up and retrace their steps.

† "Aug. 22. As I led the pack-train out this morning I felt extremely anxious as there were several places on the trail where a misstep meant certain death. At the north end of the lake the trail zig-zags up a very steep grassy slope for 800 feet and then over loose slide-rock — talus — for 1,100 feet higher to the cut-walls, which loom up 2,000 feet above the slide-rock. The trail now follows narrow ledges straight for the gap, which is on the same level and 500 yards west. At one place we climbed a narrow and very steep rock fifteen feet high, in which we had to cut steps. We led our most troublesome animals over this. My feelings were indescribable when I started up this rock, not knowing what the horse would do. The ledge was about eighteen inches wide, the upside wall sloping back. On the lower side was a fall of 1,900 feet." — From Lieut. Ahern's official report.

axemen to cut a trail. Sometimes we could travel for a few rods in the bed of the stream. Then obstructions in the form of cascades or huge rocks would compel us to cut a path up the steep banks and pursue our course along the sloping sides of the valley. The descent grew constantly steeper and our progress correspondingly difficult and slow. For four hours we toiled along in this fashion, every hundred yards in advance bringing us to greater difficulties. At last, wet to the skin, our teeth chattering with cold, and thoroughly worn out, we cleared a place large enough to put up our tents and went into camp. What a luxury a fire is under such circumstances! We had eaten an early breakfast at the foot of the lake on the other side. Since that time we had been working incessantly, most of the time in a pouring rain, until five o'clock in the afternoon found us in the condition described, two and a half miles down the Pacific slope in a dense tangle of fallen logs, thickly overgrown with brush. We had our supper, warmed ourselves, and were fairly comfortable in a couple of hours, but there was nothing for the horses to eat and we were obliged to tie them to the trees for the night. The next morning they were taken back a mile on the trail to the last grass we passed, where they were pastured for a couple of days while the men cut a trail two miles to the more open country in the valley below.

A side trip.— Leaving the main party here to rest for a few days, Lieut. Ahern and myself with the prospector, Lewis Meyer, made a four days' trip up MacDonald's Creek and over the divide to the headwaters of a branch of the East Kootanie. Our purpose was to examine the large glacier described in another portion of this paper. The route lay across a succession of ridges, ranging in elevation from 500 to 2,700 feet above their respective valleys. The lower slopes are densley wooded and fallen timber added to the work of climbing. The summits of all except the highest ridges were quite level grassy parks, with borders and patches of pines. From any of these summits a magnificent view was to be had of the great backbone over which we had climbed. Fifty miles of it could be seen at once owing to the great bend it makes to the westward.

On our return trip we endeavored to shorten our route by taking a short cut over the summit of a spur of the main range. This took us up 8,000 feet. A rapid descent of 2,000 feet was then made, and the first part of the cut off had been successfuly accomplished. After a couple of miles of easy going we started on another descent of 2,000 feet into the valley of MacDonald's Creek. We found the descent extremely difficult. It was so steep that we kept our feet with difficulty. Impassible ledges were frequently in our way and multitudes of fallen trees encumbered the less precipitous slopes. We were three hours making the first half mile. Darkness came on while we were still three miles from camp and we spread our blankets on the stony banks of the stream and lay down to wait for daylight. We had eaten the last of our rations at noon, expecting to reach camp that evening. We started on at 6 A. M., and at 10:30 rode into camp and ordered dinner.

We were now not more than eight miles from the large glacier elsewhere mentioned, and I was eager to visit it. But travel in this region is indescribably difficult; we had spent four days in the side trip I have just described, our rations were nearly gone, and we had yet nearly a hundred miles to go before we could reach our base of supplies. It was therefore plainly evident that we must move on and leave this most attractive region, in the hope that at some future time fortune may be more kind.

Mud Creek.— Our route now was down the valley of Mud Creek to the north fork of the Flathead. This stream, Mud Creek, flows between steep rocky walls from 1,500 to 2,000 feet high. They gradually grow less precipitous and the valley widens as we descend. The lower portion of the valley has been covered with a thick growth of pines. In the winter avalanches sweep down the steep slopes on either side and towards the bottom carry everything before them; not a stick or a stone is left. The debris thus accumulated is hurled into the bed of the stream and in some cases permanent dams have been thus made and lakes formed. Some of these have in the lapse of time become marshes stretching clear across the valley. These marshes are soft and miry for pack animals, hence the name Mud Creek. The existing lakes are half full of the slowly decaying trunks of the pines swept into them. A great mass of trees, earth, stones and snow, the remains of an avalanche of the previous winter still lay at the foot of one of the many wide swaths cut through the pines, a silent but eloquent witness of the destroying work of the snow.

Flathead Valley.— The great Flathead valley, although deeply eroded, is not a valley of erosion, but is a good example of a synclinal valley. It is a deep trough between the Rocky Mountain range on the east and the high ranges to the west. Its character will be seen when it is stated that if a line be measured from the summit of the Rockies to the Flathead valley, and another an equal distance out to the plains eastward, the elevation of the point on the plains will be found to be from 1,000 to 2,500 feet higher than the corresponding point in the Flathead valley. The same is true of the great Columbia-Kootanie valley of British Columbia. Dense forests of pine, spruce, hemlock, etc., crowd the valley of the Flathead and those of its tributaries on the east down nearly to Flathead lake. Here on the prairie-like openings a few ranches have been established.

GEOLOGICAL NOTES.

The plains formation. — A large portion of the beds forming the surface of this portion of the plains I judged to be Laramie. This conclusion is based only on the lithological character of the beds, as no fossils were found at any point.* Beds which I refer to the Laramie were first seen on Dry Fork, a branch of the Marias River, and they were traced from there all the way to the 49th parallel. On the Two Medicine, near the Mission, the supposed Laramie has been cut through by the stream and black shales of presumably Cretaceous age are exposed. The Laramie has a thickness here of about 500 feet. In most of the exposures seen it has a greenish color and the beds consist of an intimate admixture of sand and clay without the usual seams of lignite and with fewer concretions than are commonly observed in these beds in North Dakota. On a branch of Swift Current, near St. Mary's Lakes, the Laramie was again seen close up to the base of the mountains, underlain by soft black shale, which appears to be Benton. No tertiary beds were seen although they may exist here. The beds later than Laramie were small local fluviatile deposits still in process of formation.

The foot-hills.—The rocks exposed in the foot-hills seem to be largely of Cretaceous age, though there are some beds of limestone that can hardly be so young as Cretaceous.

Structure of the mountains.—I have already referred to the precipitous character of the east base of the mountains.† This appearance is due to the structure of this portion of the mountains. A fairly correct idea of this structure may be obtained by imagining a long fold to be fractured along the anticlinal axis, and the eastern half to fall back to nearly its original position, leaving the western half of the fold to stand at its elevated position. The plane of fracture thus becomes the eastern escarpment of the mountains and the foot-hills are the disturbed edges of the upper strata of the down-sinking eastern half of the original fold. I suppose it is altogether more probable that the eastern half never rose at all, but that the faulting was accomplished by the simple elevation of the western half. The effect is the same in either case. It will be understood I presume that the uplifted western portion does not present an unbroken wall for hundreds of miles as might perhaps be inferred from what I have said. I have spoken of a single fault; in reality there are several, roughly parallel to each other and less so with the general trend of the range. There have also been transverse fractures, or else the streams have done valiant work in cutting through the rocky walls in which their beds are made. The total result of all the forces at work

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* At Fort Shaw the Sun River runs over shales containing fossil Inocerami, beautifully preserved.

† Captain Twining, of the Boundary Commission, speaking of this region, says: "I had been led to suppose that the ascent to the summit was a gradual slope, and was greatly surprised to find that the rolling prairie abutted abruptly against an impassable escarpment of rocky precipices. It was found to be impossible to carry a continuous line even so far as the crossing of the Belly River, and the three stations at this point are connected by traverses; the connections between the two final stations are made by a traverse of thirty-five miles through the South Kootanie Pass." Report of Chief Astronomer, p. 65.

here, whatever they were, is this: The strata once continuous and level have been slightly flexed and broken into huge blocks from one to two miles in thickness, and five, ten or fifteen miles in each of the other dimensions. These blocks have been heaved up to their present position. The mountains thus formed have two features in common. The side facing the plains has been most elevated. They thus present steep walls to the east, with long gentle slopes to the west. In other respects they differ. Some of them, for example, have not only steep walls on the east, but also on the south, with a gentle slope in the other two directions. Others reverse this, having north and east facing walls, and slopes on the west and south. The structure here outlined is marked in the vicinity of the 51st parallel by an additional feature. The vertical displacement is reported by McConnell* as being over 15,000 feet, and accompanying this is a horizontal displacement or overthrust of from two to seven miles. This latter feature may occur south of the 49th parallel, but I saw no evidence of it.

Strata exposed.—The rocks exposed in the walls of the valley of the Belly River give a practically continuous section of 5,000 or 6,000 feet of strata. They are all rather thin bedded and the whole series seem to be perfectly conformable. The beds consist, from below up, of yellowish gritty limestones, red sandy shales and sandstones, and green and black shales with more limestones at the top. The colors are quite distinct and give a broadly banded appearance to the high walls which form the sides of this valley, making it easy to trace the stratigraphic relations as we ascended. The dip was slight but towards the south or away from the plains, as it is along the range farther south. As we were climbing somewhat rapidly in the direction of the dip we were steadily getting higher in the series. No fossils were seen during the trip. The sandstones often showed wind-drift structure and ripple-marks and the red shales were full of mud cracks. The black shales and limestones indicated deeper water. From base to summit there is an entire absence of crystalline rocks.

The rock exposures on the Pacific side were not so numerous, but showed the same order of the same beds, the only difference being the addition of several intercalated beds of diorite, and the fact that the strata in the mountains west of the main range have been more strongly folded. The disturbance producing this folding occurred after the intrusion of the diorite. This is shown by the fact that the latter has shared in the folding and has been much fractured in the process.

Igneous rocks.—1. Location and character of outcrops. The outcrops of igneous rocks are on the headwaters of MacDonald's Creek. The first one observed is about two miles from the summit of Ahern Pass (see 1 on map). The bed is about fifty feet thick, is smoothly interbedded with the stratified rocks of the region, and is exposed for about

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* Annual Report Canadian Geological Survey, 1886, vol. 2, p. 33D.

four miles along the side of the valley. Five miles down the valley on the other side another outcrop about an eighth of a mile long occurs. (See 2 on map.) It has the same thickness and general character as the first mentioned.

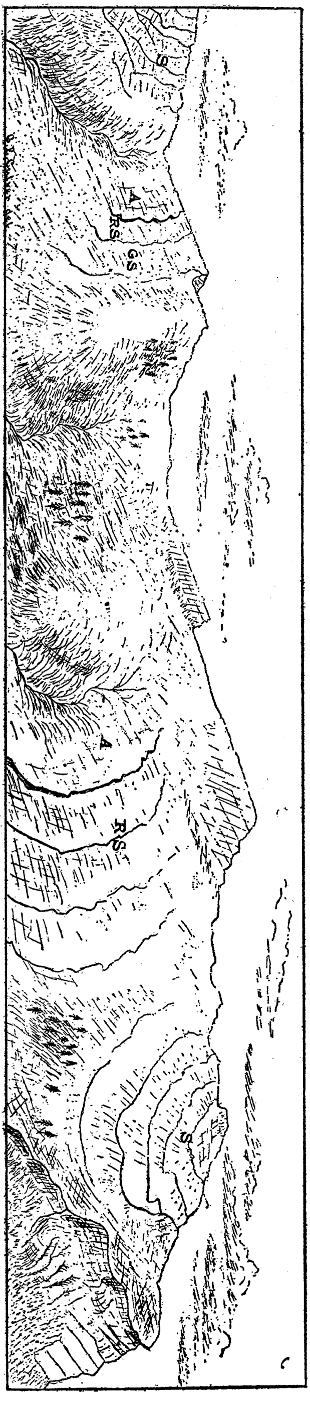
These two exposures are on the east fork of MacDonald's Creek. On the west fork of this stream, at its source, a very extensive exposure is found. This valley is continuous with that of a stream flowing in the opposite direction, a branch of the East Kootanie.

The western wall of this common valley is lined with a sheet of diorite (see 3) from the bed of the stream up to a height of a thousand feet. The slope is about 20° from the horizontal. For at least a half a mile this sloping wall of rock has been smoothed and planed by the ice, and so enduring is the rock that the glacial polish still shows plainly. This bed has about the same thickness as the others.

A fourth exposure occurs a mile down the valley on the Kootanie side (see 4).

Other exposures seen at a distance occur north of Mt. Ruger (see 5).

The uniformity in the character of this rock, macroscopically at least, over such a large area is noteworthy. The same may be said of the manner of occurrence. The sheets have been intruded between the stratified beds so neatly as to present the appearance of being original members of the series. The thickness too is remarkably uniform, averaging about fifty feet. The shales near the contact, above and below, have been abaked and



On the head waters of McDonald's Creek: S.=shale; R. S.=red shale; G. S.=green shale; A.=beds of diorite.

hardened by the heat and pressure. The diorite sheet, although in some exposures the surface formation and in others hundreds of feet below the surface, is nevertheless found at very nearly the same geological level in each of the exposures.

2. *Petrographical notes.*—The petrographical study of this mass of rock has been made on four specimens, three of which are from the locality marked 1, where a cliff almost forty feet high is capped by a green sandy shale. Specimen 1 is from near the bottom of the cliff, perhaps thirty feet from the contact. Specimen 2 was taken from a point about twenty feet, and specimen 3 about ten feet below the contact, so that the specimens show in inverse order the gradations in characters of the rock in passing from the contact toward the center of the mass. The sedimentary rock of the cap is well baked. The other specimen of the eruptive rock which has been sectioned is from the contact with shale at locality 3, and shows portions of both rocks in the section.

The rock is all cases much decomposed. Specimens 1, 2 and 3 show a steady decrease in the coarseness of texture, the crystals in No. 1 having average dimensions of from one to two millimeters, with occasional hornblende crystals sometimes attaining to a half centimeter in diameter. The crystals in No. 2 will average about one-half, and those of No. 3 about one-fourth these dimensions.

All the specimens from locality 1 have a more or less apparent granitic structure with a tendency to porphyritic development of the hornblende. A dull greenish lustre so characteristic of rocks of this type is apparent in all, but somewhat irregularly distributed. The lens reveals in the coarser specimens feldspar, augite, hornblende, black ore material and pyrite. When the rock was powdered a considerable portion of the ore material was strongly attracted to the magnet, indicating magnetite. In addition to the minerals above mentioned the microscope reveals in all sections ilmenite, leucoxene, quartz, chlorite, zoisite, and apatite. Section 2 contains well crystallized sphene and section 3 epidote as well as sphene.

The more coarsely crystalline of the three shows in section a plagioclase which is very much decomposed and is associated with more or less micro-pegmatite. The nature of the alteration seems to be saussuritization, zoisite being identified as one of the products by its moderately high index of refraction, its parallel extinction and low interference colors. Augite and hornblende are present in about equal proportions, but the crystals of the former are much larger than those of the latter. The hornblende is the brown variety with deep colors. The absorption is $c > b >> a$. It is always well outlined and shows perfect prismatic cleavage. It is very unstable, the initial stages in the alteration consisting apparently in a change of color to green, followed by a decomposition to chlorite. This decomposition has in some cases proceeded so far as wholly to replace the crystal, in other cases the chlorite occupies but one half of the crystal or appears in inclosed areas within the crystal. The chlorite is strongly pleochroic (yellow to green), and is often radial (delessite.) Both hornblende and augite are frequently twinned. The small amount of quartz not in the form of micro-pegmatite may be either original or secondary. The black ore material shows in some cases in square sections and is strongly attracted to the magnet in the rock powder. Yet many grains are almost entirely changed to leucoxene, indicating the presence of titanium, probably as ilmenite. Apatite is present though not in great abundance.

Section 2, from a specimen taken at a point about ten feet nearer the contact, shows besides a more finely crystalline texture than section 1, certain differences in mineralogical composition. It contains more quartz than micro-pegmatite. The feldspar is more altered. The magnetite shows a greater tendency to appear in skeleton growths, and well crystallized sphene, as well as considerable leucoxene is present. As in specimen 1 the augite is but little altered, while the hornblende is in many cases much decomposed to chlorite.

Section 3 shows very beautiful skeleton forms of magnetite, long and slender growths running entirely across the field with a magnification of thirty. Imperfect parallel growths of brown hornblende about augite are seen much as they have been described in the augite diorite from Somerville, Mass.,* with which this rock presents many analogies. Like section 2, this section contains sphene, and epidote was made out, probably a product of the combined alteration of feldspar and hornblende. The characters of this rock as made out in the three sections agree well with those of the camptonites of Rosenbusch.

In section 4, from the contact of the igneous intrusion with metamorphosed green shale (locality 3 on map), the decomposition is too great for the section to be of great interest. It can be seen, however, that the feldspar was in lathshaped crystals with perfect outlines, oriented without reference to one another. The structure is that of a typical diabase. Between the altered feldspar laths is a mass of decomposition products of a greenish or dirty brown color in which chlorite is made out, and the mass is crossed by serrated magnetite skeletons. No distinct crystals of either hornblende or augite can be made out, and it seems probable that both hornblende and augite are entirely altered.

In order to form reliable conclusions as to the dependence of the rock characters on the distance from the contact, observations should be made on a larger number of sections at several localities somewhat widely separated. The evidence obtained so far as it goes, seems to be, (1) that there is a gradation in texture, the finest grained rock being nearest the

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* Wm. H. Hobbs, on the Petrographical characters of a Dike of Diabase in the Boston Basin: Bull. Mus. Comp. Zoöl., Harv. Coll. xvii. Plate 1, fig. 2, March, 1888.

contact; (2) that the diabase structure is restricted to portions of the mass which consolidated quite near the the contact; (3) that nearness to the contact measures the tendency of the magnetite to appear in skeleton forms; (4) that the hornblende and augite show more tendency to crystallize in parallel growths nearer the contact.

In his study of the diabase dykes of the Rainy Lake region,* Dr. Lawson has shown that in some cases a porphyritic structure, a diabase structure, and an allotriomorphic-granular or granitic structure in turn characterize the rock of a single dyke in passing from the contact toward the center of the dyke. The conditions of consolidation of the rocks here studied have not been such as to give rise to the formation of a porphyrite, but with that exception the observations are quite similar.

EXISTING GLACIERS.

At the close of his interesting paper on this subject, Mr. I. C. Russell† writes as follows: "Existing glaciers were discovered by Prof. Pumpelly during the progress of the Transcontinental Survey, at the head of the Flathead River in northern Montana. No scientific account of these observations has yet been published; but I am informed by Prof. Pumpelly that two glaciers were seen in the mountains in which the East Fork of the Flathead rises at an elevation of about 7,000 feet. It was observed that the glaciers broke off suddenly at the summit of precipices 2,000 feet high and that the waters flowing from beneath the ice had the milky color characteristic of glacial streams. The mountains in which these glaciers were discovered extended northward into British America, and are supposed to reach their greatest elevation north of the boundary. It seems safe to predict that when this little known region is more fully explored additional glaciers will be found about the peaks known as the Crows and Mountain Head." I am unable to determine from this account just where the glaciers seen by Prof. Pumpelly are. Two glaciers answering almost perfectly to the description here given are plainly visible from the crest of the Milk River ridge, and from very many points on and near the International Boundary. These glaciers, however, are on the head-waters of the Belly River, a fact which could not escape Prof. Pumpelly's notice had he come near enough to see the milky color of the water. He would also have seen that there were four instead of two glaciers; hence I conclude that these are not the ones referred to by him.‡ Small glaciers are numerous in all the higher mountains within twenty or thirty

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* Petrographical Differentiation of certain Dykes of the Rainy Lake region: Am. Geol., March, 1891.

† Existing Glaciers of the United States: 5th Ann. Report U. S. Geological Survey, p. 347.

‡ Since the above was written I have seen Prof. Pompelly and find that the region referred to is northwest of the Cut Bank Pass, between MacDonald's Creek and the main divide of the Rocky Mountains. It seems entirely probable that this glacier is in the same mountain mass as those described in the present paper.

miles of the boundary, but are more numerous and larger on the north slope of the portion of the range which bends to the west, and especially on a spur or branch of the main range nearly parallel with this same portion of it and some miles farther south. Judging from what I saw I presume there are twenty or thirty glaciers in this region. Several terminated at the crest of high precipices with falls varying from 500 to 2,500 feet. The thunderous roar produced by these ice falls is unlike any other sound I have ever heard. The nearest approach to it is that of distant thunder. In each of the cases of this kind observed save one the ice did not again accumulate at the foot of the fall, but melted as soon as it reached the lower level. In the single exception noted the fall was probably not over 500 feet and the direct rays of the sun did not fall upon the ice, which accumulated and moved on down the lower slope pushing its moraine ahead of it. One fair sized glacier on Quartz Creek extends down into the bed of a little lake which it supplies. Most of the glaciers were wider than long, their length being apparently determined by the shadow of the parent mountain.

The Mt. Dana glacier, described and illustrated by Mr. Russell* is a good type of the average glacier in this region. One somewhat larger than that glacier was made the object of our only side trip for any such purpose. It lies in a small amphitheatre at the head waters of the East Kootanie near the 114th meridian, about fifteen miles from the boundary. Its width is about two miles and its length one and a half. Although it is on the northeast side of the mountains a large part of its surface is exposed to the sun's rays fully two-thirds of the day. Its surface is remarkably smooth and free from crevasses. Its front is oval, like an inverted wash-bowl, and it is so steep that it can be ascended at only one or two points. The thickness of the ice a few hundred feet from the edge was estimated at from 250 to 500 feet. On gaining the summit of the glacier it was found to stretch away smooth and nearly level to the adjoining mountain. Patches of morainic supplies and scattered bowlders were seen here and there on the front half. There was no dust upon the surface, nor were there any dirt bands in the ice. The terminal moraine of this glacier is quite imposing. Approaching its highest part from without, one must climb 100 feet to reach the summit; from there down to the edge of the ice, forty feet at the time of my visit. This was not, however, the bottom of the moraine. It varies at other points down to perhaps fifteen feet in height. Its length is fully two and one-half miles, and it varies in width from 150 to 400 feet. It is composed wholly of somewhat subangular stones, varying in size from tiny bits up to huge blocks weighing forty or fifty tons. Six parallel ridges of rock-fragments on the inner slope of the central portion of the moraine indicated as many successive advances and retreats of the ice.

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*5th Annual Report U. S. Geol. Survey.

Whether these advances and retreats were annual I could not tell. We camped for the night near the banks of one of the milky streams flowing from the ice, and found in the morning that the volume of the stream had fallen off about one-third, and the water was much clearer. I concluded therefore that not only the melting, but the motion also of this glacier depends largely on the heat of the sun. The slope on which it lies is quite gentle. A few miles down the valley an older moraine, some four miles in length but much lower than the present moraine, indicates a stage in the recession of the large glacier of which the present is the shrunken remnant only. The glacier just described was the largest seen close at hand. Indeed only one was seen in the whole region that was larger. This, if it be a true glacier, is much the largest in the United States, exclusive of Alaska.* We saw it from many points, at distances varying from eight to twenty miles. It lies in a horse shoe shaped basin or valley at an elevation of about 7,000 feet and covers, as near as I could estimate, an area about four by six miles in extent. We passed half way around it but did not find the stream that must flow away from it, unless a somewhat remarkable branch of the Belly River has its source there. This stream flows out from the foot of a precipitous wall, fully 2,000 feet high, forming the northeast face of the continental divide. The rocky wall has not a fissure in its face from top to bottom. The ice field lies on the opposite side of the ridge fully ten miles away and 2,000 feet above the point where the stream comes forth. The latter has the milky character common to glacial streams and flows from the direction of the large ice field. The strata dip from the ice field in the direction of the stream. Further evidence of its relationship must await future investigation.

FORMER GLACIERS.

Western border of drift.—So far as my observations extended the portion of the plains traversed by us is entirely devoid of drift material, with exceptions hereafter noted. Dr. G. M. Dawson,† in a journey from Fort Benton on the Missouri, to Fort McLeod, British Columbia, found bowlders all the way. As his route was some sixty or more miles east of mine, it would seem that the western limit of drift material lies between these two routes, and as Dr. Dawson found undoubted Laurentian erratics at or near the 113th meridian on the international boundary, it is likely that the western limit of drift for 100 miles south of the boundary is somewhere from forty to fifty miles east of the base of the mountains.

Ice tongues of the eastern slope of Rocky Mountains.—Several ice tongues have at some time descended from the range on the west and

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* The location of the large glacier was in some way left out from the original map. Its location on the present map is only a guess at the correct place.

† Report of Progress of Geol. Survey of Canada, 1882–84, p. 147C.

have plowed their way nearly at right angles to the range, and consequently directly in the face of the great Laurentian ice sheet for many miles out on to the plains. The trough-shaped depressions made by these alpine glaciers are now sometimes occupied by small lakes walled in on all sides except towards the mountains by the old moraine. Sometimes the water has cut through the morainic walls and completely drained the lake. In such cases it usually happens that the swaying of the stream from side to side has cut away the whole front portion of the moraine, leaving two long parallel ridges on either side extending back along the course of the stream to the mountains. In still other cases the troughs once occupied by the ice are dry and empty. Measured on the plains these ice tongues varied from five to forty miles in length and from half a mile to five miles or more in width. Of their mountain extensions I shall speak later. Their thickness can in some cases be inferred from the appearance of the moraines. These are much higher on the ice side than on the outer or plains side, as would be expected, since the ice came down upon the soft Laramie beds at a steep angle. The glacier which plowed out the beds of St. Mary's Lakes was the largest of all in this region and must have been of no mean proportions. These lakes, two in number, lie at nearly the same level, the one just outside the narrow belt of foot-hills, the other extending through the foot-hills reaches the very base of the mountains. The lower lake is about five miles long and two wide; the upper is seven or eight miles long, but not more than two miles wide. The stream discharging them is 150 feet wide, three feet deep, and very swift. From our camp at the foot of the lower lake the stream seemed to have cut through a moranic wall about 300 feet high a few hundred yards below the foot of the lake. I found, however, on climbing up this slope that the ice had ridden over the seeming wall, which was not a moraine at all, but a terrace marking the depth of post-glacial erosion of the stream. The topography of this upper level was unmistakably that of a ground moraine, yet there was something unfamiliar about it which I was at first unable to interpret. There are three glacial lakes on this terrace, one a mile in diameter, and the whole region showed unmistakable evidence of having been covered with water since the retreat of the ice. On the sides of the Milk River ridge, which forms the eastern walls of St. Mary's valley, terraces, a dozen or more, extend up to a height of at least 800 feet above the present level of the lakes. These, with the peculiar outline given to the knobs and hills, constitute the unfamiliar features spoken of. I followed down the valley five miles or more, but saw no signs of a terminal moraine or barrier ridge of any sort that could have held the waters at such a level as is indicated by the terraces. I concluded, therefore, to adopt tentatively the hypothesis that the Laurentian ice sheet was the barrier; that it had sent a tongue up the St. Mary's valley far enough to pond back the waters and form the lake whose terraces I had seen. The southern extension of this lake was the steep-walled fiord-like valley of the upper St. Mary's Lake. On the east the water was held in by the Milk River ridge; on the west by the mountains. How far north it extended would depend on the position of the hypothetical ice barrier. Lack of time prevented further investigation of this region.

Ice records west of main range.—After crossing the continental divide the valleys on the western slope were found to give evidence of heavy glaciation. Planed surfaces and trains of bowlders were common but were confined to the valleys. Bowlders of undoubted glacial origin were found at an altitude of 7,250 feet.

ORIGIN OF THE ICE-TONGUES OF THE EASTERN SLOPE OF THE ROCKY MOUNTAINS.

In passing up along the eastern flank of the Rockies, as we came near enough to them to begin to encounter the moraines of the ice-streams spoken of in a previous paragraph, certain crystalline bowlders were occasionally observed. On examination they proved to be a rather fine-grained diorite.

As we moved up the valley of the Cut-Bank these bowlders grew quite numerous.

In the trip to the summit of Cut-Bank Pass it was confidently expected that the outcrop of this diorite would be found. However, although the bowlders were to be seen all the way, the rocks in place seemed to be wholly of sedimentary origin and were very little if at all metamorphosed.* The failure to find the igneous rock was accounted for by supposing that it might now be hidden by debris from the cliffs above it. A second ascent was made up the Swift Current with no better results so far as finding the diorite was concerned. This valley is twenty miles from that of the Cut-Bank and there is no communication between them; but diorite bowlders occur in this valley also.

The third ascent was by way of Belly River. As before stated, the bare walls of this valley afford no hiding place for beds of any prominence whatever. The exposure is peacticaly continuous for fifteen miles from the summit. No diorite or other eruptive or crystalline rock occurs in place in this valley. At the head of this river on the summit of Ahern Pass, at an altitude of 7,250 feet, bowlders of the diorite, some of them glaciated, were quite abundant.

Some ten or twelve hundred feet below the summit, on the Pacific slope, a mile and a half from the pass, the diorite was found in place. The exposure is four miles in length. It occurs on both sides of the valley, which is fully a mile wide.

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* Diorite bowlders were seen however within 800 feet of the summit, at 7,000 feet elevation.

There are many other exposures on the upper waters of McDonald's Creek, where the diorite is the surface formation and is strongly glaciated. On the divide between the East Kootanie and McDonald's Creek, the sloping west wall of the common valley is a bed of this diorite. It has been planed and smoothed for a thousand feet from the bottom of the valley by the ice stream that once flowed through this gap.

In brief, then, the evidence is this:

1. Trains of diorite bowlders were traced from the plains east of the mountains up to the axis of the range, along three lines widely separated from each other.
2. No outcrops of diorite could be found on the eastern slope on any of these lines.
3. Extensive, heavily glaciated outcrops occur on the western slope 1,000 feet below the summit of Ahern Pass.
4. On the Belly River line, the bowlder train was followed over the summit of Ahern Pass, down the western slope to the parent ledge.

From these facts, then, it seems clear that the ice-tongues which crept down the valleys on the east slope of the Rockies, and plowed their way out some miles beyond the foot-hills, did not originate on the east side of the range; but were pushed up over the continental divide through the gaps and passes mentioned, and probably through others not yet examined, by some force from the west. What that force was, admits of but little question. That it was an ice sheet of some vigor is obvious. That it was separate and distinct from the Laurentian ice sheet, at least to high latitudes, is equally clear. Dr. Dawson has brought forward evidence* to show that a great ice sheet which he has called the Cordilleran Glacier once occupied the region between the Coast Range and the Rocky Mountains in British Columbia, and later he has found evidence† that the ice ran through the gaps in the Coast Range and down to the sea.

President Chamberlin‡ has shown that the ice extended southwest to the vicinity of Lake Pend d' Oreille, Idaho. Mr. Bailey§ Willis has found similar evidences in Washington. Neither of these observers, however, connect the ice records seen by them with the Cordilleran Glacier.

From such observations as I was able to make, it is my impression that the ice ran in the valleys, in streams whose courses were determined partly by the source but mainly by the mountain topography. The region lying between the main range on the east, the Rocky Mountains

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* Quart. Jour. Geol. Soc., vol. 31, p. 89, and Quart. Jour. Geol. Soc., vol. 34, p. 72.

† Geol. Mag. Decade III, vol. 5, 1888, p. 347.

‡ Bulletin No. 40, U. S. G. S.

§ Ibid.

proper, and the Cascade range is very mountainous. The ranges are broken and irregular. Short spurs and ridges trending in various directions give rise to a net-work of valleys. Through this labyrinth the ice-streams made their way. Some of them found more or less direct passage into the great Flathead valley and there died a natural death. Others were caught by the transverse spurs and carried up over the main range from whence they descended to the plains on the east.

The tendency toward a southerly movement may indicate a northern origin for the ice. It is evident, however, that local supply would be abundant, if, indeed, it might not be sufficient to account for all the glaciation observed.

MADISON, Wisconsin, December 29, 1891.

ON A NEW OCCURRENCE OF OLIVINE DIABASE IN MINNEHAHA COUNTY, SOUTH DAKOTA.

By G. E. CULVER and Wm. H. HOBBS.*

Field Notes.— The rock considered in this paper occurs in the southeastern part of South Dakota, in Minnehaha county. The country rock is the Sioux Quartzite, large outcrops of which occur throughout this and adjoining counties.

The quartzite lies in gentle folds with axes approximately east and west. In the vicinity of the diabase the dip is to the south at an angle of 8° the outcrop being on the north of the diabase.

The surface of the latter lies somewhat below the general level of the district, in the valley of one of the small tributaries of the Big Sioux.

The stream has cut a trench twenty-five or thirty feet deep and a mile in length directly through the diabase. Whether this represents the width or the length of the mass it is impossible to say, there being no other exposures.

No actual contact with the quartzite could be found, but from the fact that undisturbed beds of the latter occur very near the diabase, it may be inferred that the latter is older than the quartzite, and may have been an island in the sea in which the quartzite was deposited.

On the other hand the diabase gives no indication of having been poured out upon the surface. Not only is it completely crystalline but the size of the crystals indicates slow cooling. The only way in which it seems possible to harmonize these facts is to suppose that the ancient rock with which the diabase was once covered had been entirely removed before the deposition of the quartzite. Such a supposition must rest on very insufficient data at present however.

No other eruptive rock occurs in either Dakota outside of the Black Hills, 300 miles away, but some seventy or eighty miles northeast of this locality, in the Minnesota valley, there are many outcrops of eruptives in the gneisses and other ancient rocks of that region. In order to compare the South Dakota diabase with these rocks, the best exposures in the neighborhood of Granite Falls, Minnesota, were visited and specimens collected representing a dozen or more varieties. Macroscopically, none of these bore very close resemblance to the South Dakota diabase.

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* Field notes by G. E. Culver and petrographical notes by Wm. H. Hobbs.

Unfortunately the specimens were lost before sections had been made from them so that the comparison was not carried to completion.

Perhaps the most prominent field characteristic of this rock is the profound decomposition it has suffered. How much of it has been removed by erosion it is impossible to say, but the whole exposure from its upper surface down to the bed of the stream, a distance of twenty to twenty-five feet, seems to be thoroughly disintegrated. It apparently maintains its vertical position only by the support of a net-work of thin quartz veins which ramify through it in all directions.

The decomposition has brought out a set of lines indicating a horizontal movement in the fluid mass. Parallel with these apparent flowage lines, a layer of bowlders of decomposition, well rounded, but still *in situ*, extends for some distance along the bank of the stream. The rock below this layer of bowlders is as much decomposed as the upper portion. The limit of decomposition seems to be marked by the position of the stream. The rock in its bed is firm and apparently unaltered.

Just below the lower end of the diabase exposure, an excavation was made to determine if possible the relations of the diabase to a bed of siliceous flour which occurs there. (Another bed of this material occurs about a mile farther down the creek resting on the quartzite.)

About two feet below the surface a layer -- not continuous — of steatite about two inches thick was encountered. Immediately below this steatitic layer was a stratum of the same material containing hard fragments up to a quarter of an inch in diameter. Whether these were fragments of sound diabase, or pieces of the quartz veins was not determined. Below this the rock became gradually more firm so that at a depth of six inches a pick could be driven into it with difficulty.

It does not appear that the extensive decomposition of this rock is due to any inherent tendency in that direction, but rather to the peculiar circumstances of its history.

In the warmer and moister portion of our country south of the glaciated area — in fact, in any unglaciated region where ancient crystalline rocks occur, extensive and profound decomposition very commonly occurs.

This rock, however, is in the more arid portion of the glaciated area. The surface of the adjacent quartzite is planed and scratched after the orthodox glacial fashion.

Within half a mile of the diabase outcrop, on a tabular surface of quartzite, two distinct sets of striæ occur. One set runs S. 20° E. and the other S. 50° E., indicating at least two ice movements.

These visitations of the ice must have swept off all previously decomposed material from the diabase, so that the present accumulation is in some degree a measure of the work of the destructive agencies since the second of the two ice invasions to which reference has been made.

Further light is thrown on this question by the fact that in its final advance the ice did not overrun this particular region. Hence whatever accumulation there was as a result of inter-glacial decomposition was preserved to be added to by the same disintegrating forces in post-glacial time.

If one were inclined to jump at conclusions, the inference would be easy, that since rocks very similar to this, both in character and age, within the region covered by the ice in its last advance show almost no accumulation of decomposed material, while this rock, perhaps equally enduring, but lying just without the area of the last advance, is so deeply decomposed, therefore the time between the second and the last advance of the ice is much greater than that which has elapsed since its final retreat.

This evidence would have more value as a time measure if there were other exposures of the same rock within the adjacent latest glaciated area. Unfortunately none occur. Of those that do occur from the granites near Big Stone Lake to the basic eruptives at Granite Falls no one of them, so far as can be learned, exhibits any appreciable accumulation of decomposed material. The same is true of this class of rocks in Wisconsin and northern Michigan and generally throughout the northern United States and Canada.

So far as it goes, then, the testimony of this rock falls in with that which has been derived from comparisons of the till of the earlier and the later glacial epochs. These comparisons all go to show that inter-glacial time was vastly longer than post-glacial time.

Petrographical Notes.— The fresher rock is a very coarse-grained olivine diabase. The hand specimen shows lath-shaped twinned feldspars over a quarter of an inch in length, sometimes with a dull greenish hue as though partly changed to saussurite. Large columnar augite crystals, penetrated in all directions by feldspar, show in some cases cleavage faces over an inch in length. Spotting these cleavage surfaces are small yellow-green grains of olivine. Considerable black ore material and a little pyrite can also be made out under the lens. After the rock was pulverized the black ore material was strongly attracted to a magnet and when dissolved in hydrochloric acid in presence of tin gave no titanium reaction.

The microscopical study was made on two sections from one of the bowlders near the bed of the stream. In both the diabase structure is typically developed, the lath-shape feldspars penetrating the other constituents in all directions. No evidences of disturbances are visible, except such as are explained by movements in the partially consolidated magma. There are present besides feldspar, augite, olivine, hornblende, biotite, ilmenite, apatite and clorite.

The feldspar is polysynthetically twinned according to both the ordinary laws, and is only moderately altered. Determinations by Michel-

Levy's or Pumpelly's method of measuring the extinction angle in those sections which give symmetrical extinctions (zone of $\bar{b}$), furnished a maximum value of 28°, making it probable that the feldspar is labradorite. A tolerably fresh piece gave a specific gravity of 2.695. Some crystals show a decided cloudiness, which is found to be due in part at least to the formation of a colorless micaceous mineral.

The augite, which is penetrated in all directions by plagioclase laths presents some interesting characters. The usual cleavage parallel to the prism is well marked with good partings parallel to one or both of the vertical pinacoids. In some basal sections all four of these are well developed. The color of the mineral is reddish to yellowish-brown, but with varying depth of tone, and sometimes grades into an olive near the periphery of the section. The dichroism of basal sections is most marked, the ray vibrating parallel to the plane of symmetry, being yellow-brown with a slight tinge of red, and that vibrating in the perpendicular direction being distinctly red-brown. The monoclinic symmetry of the mineral is evinced by the inclined optic axis always obtained in sections which show nearly perpendicular cleavages, and by the high extinction angles (as high as 45°) in those sections which show but one cleavage. A brown or greenish brown hornblende is sometimes found as a partial peripheral zone about or inclosed within augite crystals, generally with approximately the same orientation as the augite. It appears to be original, its position being explained by parallel growth. The hornblende cleavage and the marked pleochroism serve to identify it. The pleochroism is $\overset{|}{c}$ deep blue-green or brown, $\overset{\perp}{b}$ deep green or brown, and $\grave{a}$ light green or light reddish brown. The absorption equation is $c = b > > a$. In one of the two sections there is considerable green hornblende in good crystals, grouped about areas filled with more or less unresolvable material (probably both hornblende and chlorite and doubtless pseudomorphs after olivine crystals).

Olivine is present in one of the sections in crystals which are identified by their peculiar hexagonial outlines, colorless character, rough surface, parallel extinction, imperfect cleavage, and large optical angle in the plane perpendicular to the cleavage lines (base). In this section the mineral is in many cases remarkably fresh, showing along cracks, however, a small amount of a bluish green substance which is also to be found about crystals. There are also small, more or less irregular areas particularly abundant in the vicinity of ilmenite, which are in part red-brown and pleochronic and in part greenish. The brown parts are made out to be brown hornblende, and the green portions chlorite, in part of the variety known as delessite. The chlorite sometimes shows very marked pleochroism from intense orange to bluish green, and has slightly inclined extinction. It is clear from the disposition of the chlorite that it is the alteration product of the hornblende as well as of the olivine, and it is probable that in some cases at least the hornblende is an intermediate stage, the alumina necessary for the alteration being obtained from feldspar. Cores of olivine are found in some crystals that are more than half altered. In the second of the two sections no olivine is present, but patches of more or less opaque green or brown substance indicate the position of the original mineral.

In both sections a little biotite is present in fresh blades which give the marked mottled appearance just before extinction between crossed Nichols. Apatite is abundant in crystals of moderate size, sometimes, though rarely, broken across. Fluid inclusions in the apatite are rare. Magnetite is quite abundant in large crystals which frequently show skeleton forms, and there is a little pyrite.

The rock is therefore a coarse-grained and feldspathic olivine diabase. Examination of a larger number of sections would quite likely add some characters to those that have been mentioned. The presence of a talcose mineral in the decomposed rock observed at the locality is not explained by examination of the sections. It doubtless arises mainly from a profound alteration of the pyroxene constituent, which in the sections is almost unaltered.

ON THE DEEP WATER CRUSTACEA OF GREEN LAKE.

BY C. DWIGHT MARSH.

During the past two seasons I have become interested in the deep water fauna of Green Lake, and have made a large number of collections. While the results may not be particularly striking, I think they are of sufficient interest to warrant the presentation of a short paper on the subject. Because of its depth, Green Lake resembles, in the conditions controlling animal life, the larger bodies of water, and might be expected to have a fauna somewhat different from that of the shallower lakes. My collections seem to justify this expectation.

It is only within a few years that it has been deemed worth while to make any investigation of the fauna of deep water. Even after the existence of a very rich pelagic fauna in the oceans was recognized, bodies of fresh water were almost entirely neglected. Now, it is well known that our lakes have a pelagic fauna rich in individuals, if not in species, and a less abundant abyssal fauna. Most of the European lakes have been explored with more or less thoroughness. Especially noticeable is the extended work of Prof. Forel upon Lake Geneva and the smaller Swiss Lakes.

In this country comparatively little has been done. Since the initiatory work of Dr. Hoy in Lake Michigan, some twenty years ago, so far as I know, only two persons have published anything on this subject — Prof. S. I. Smith, and Prof. S. A. Forbes.

The bottom of Green Lake, in the deeper parts, is a fine blue clay, in which are great numbers of ostracod shells and some few shells of molluscs. I submitted the molluscs to Mr. C. T. Simpson of the United States National Museum, who tells me that there was nothing of especial interest among them. They were all littoral forms, and, in most cases, probably washed in from shallower water.

There were also several species of hydrachna, worms, and infusoria, which I have not worked out. The crustacean fauna is extremely abundant, although the number of species is small.

The following species were noted:

Diaptomus sicilis Forbes.
" *minutus* Lillj.
Epischura lacustris Forbes.
Limnocalanus macrurus Sars.
Cyclops fluviatilis Herrick
" *serrulatus* Fischer.
Canthocamptus sp.
Cypris sp.
Daphnella brachyura Baird.
Ceriodaphnia reticulata Jurine.
Daphnia kalbergensis Schoedler.
Bosmina sp.
Alona glacialis Birge.
Leptodora hyalina Lillj.
Pontoporeia Hoyi Smith.
Mysis relicta Loven.

There were, besides, several forms of *cyclops*, which seem to differ from any described American species. As I am now engaged in a study of this genus, I will leave their description for a later publication. None of the species of cyclops which I have found is peculiar to the deep water, as I have found the same forms in the littoral zone of the lake, and in smaller bodies of water in the vicinity.

The pelagic fauna consists mainly of the following species: *Diaptomus minutus* Lillj; *Diaptomus sicilis* Forbes; *Epischura lacustris* Forbes; *Limnocalanus macrurus* Sars; *Daphnia kalbergensis* Schoedler; *Leptodora hyalina* Lillj. All of these, with the exception of *limnocalanus macrurus*, come to the surface at night. The species of *cyclops* are represented very sparingly, and *canthocamptus*, *daphnella*, *ceriodaphnia*, and *alona* are quite rare. Evening collections showed vast numbers of *diaptomus minutus* and *epischura lacustris*, and in some cases of *leptodora hyalina.* I found *bosmina* very abundant in November, but rather rare in the summer months. The *abyssal crustacea* are *cypris*, *pontoporeia Hoyi* Smith, *mysis relicta* Loven, and perhaps some of the forms of *cyclops.* Especial interest, perhaps, attaches to three species of the preceding list.

Diaptomus minutus Lillj. is found in great numbers, being much more abundant than *diaptomus sicilis* Forbes. My specimens correspond very closely to the description by Lilljeborg, as given in "Revision des Calanides d'Eau Douce," by Guerne and Richard, differing only in the following particulars. The joints of the right fifth foot of the male are shorter and stouter, and the terminal claw is longer and somewhat more slender; the lateral spine on the last joint is blunt. The inner ramus of the left foot is more nearly elliptical. The animal averages somewhat smaller than the type. These differences are so minute that I consider them only varietal, although they are constant in the specimens I have examined.

Diaptomus minutus has been found, hitherto, only in Greenland and Newfoundland, although it seems probable that it is widely distributed over the northern part of North America.

Pontoporeia Hoyi Smith, has been found, hitherto, only in Lake Superior and Lake Michigan. A species almost identical with it, *pontoporeia affinis* Kroyer, occurs in the abyssal fauna of the Scandinavian lakes.

Mysis relicta Loven, was first found in the Scandinavian lakes. It is so closely allied to *mysis oculata* Kroyer, a marine form found off the coast of Labrador and Greenland, as to be considered only a variety of that species. It was found in Lake Michigan by Dr. Hoy, receiving the name of *mysis diluvianus* from Prof. Stimpson. Later, Prof. S. I. Smith collected specimens in Lake Superior. I have not had an opportunity to compare my specimens with those from the Great Lakes, or with the original description of the Scandinavian form, but I have little doubt that they are identical with them.

When we compare the deep water crustacea of Green Lake with those of Lake Michigan and Lake Superior, as shown in the lists published by Prof. Smith and Prof. Forbes, we find a striking similarity. That this should be true of the pelagic fauna is not strange, for it is easy to explain the migration of such forms from one body of water to another through the agency of water fowl.

The presence of *pontoporeia Hoyi*, and *mysis relicta* however, is not so easily explained. They are abyssal forms, found only in deep water, and never coming to the surface. Their presence in the Scandinavian lakes is explained by supposing that the bodies of water, in which they are found, were formerly connected with the sea, and that, when the access of salt water was cut off, the change to fresh water was so gradual that the animals accustomed themselves to their new conditions of existence. They belong to the "fauna relegata" or "relickten-fauna" of the Germans. This explanation does not seem to apply to Green Lake. The lake is of glacial origin, a dam of drift at the western end preventing its waters from flowing into lake Puckaway. The outlet of the lake is a small stream flowing through the village of Dartford, and emptying into the Fox River. So far as I know, there is no geological evidence whatever of any connection of Green Lake with either the Mississippi Basin or the Great Lakes, by which these deep water animals could have migrated to their present location.

The problem is one for which I can at present offer no solution.

NOTES ON DEPTH AND TEMPERATURE OF GREEN LAKE.

BY C. DWIGHT MARSH.

Green Lake is situated in Green Lake county, and is something over seven miles in length, and rather less than two miles in its greatest breadth. It extends in a northeast and southwest direction, and is considered by geologists, to be of glacial origin, its shores at the western extremity being formed of drift hills.

The lake is of especial interest because of its depth, it being, I think, the deepest lake within the limits of the state.

While at various times soundings have been made by which the deepest parts of the lake were located with a fair amount of accuracy, the only attempt at systematic soundings was made some years ago by Prof. C. A. Kenaston, when he was connected with Ripon college. Through the kindness of Mr. Henry Wolcott, of Ripon, I was enabled to get the results of Prof. Kenaston's work. The soundings were made in winter through the ice and the distances between stations chained off.

Four lines of soundings were made: from Bowen's cottage to Oakwood Hotel, from Sandstone Bluff to Oakwood, from Sandstone Bluff to Sherwood Forest, and from Sandstone Bluff to Sugar Loaf. The following tables give the results:

From Bowen's Point to Oakwood.

Distance.	*Depth.*
64 rds.	63 feet.
192 "	96 "
256 "	84 "
272 "	97 "
288 "	90 "
304 "	20 "
320 "	61 "
336 "	66 "
352 "	53 "
384 "	38 "
432 "	49 "
464 "	41 "
626 "	Shore.

From Sandstone to Oakwood.

Distance.	*Depth.*
27 rds.	52 feet.
43 "	89 "
59 "	144 "
75 "	160 "
91 "	160 "
155 "	151 "
267 "	88 "
315 "	27 "
363 "	25 "
395 "	48 "
427 "	22 "
491 "	Shore.

From Sandstone to Sugar Loaf.

Distance.	*Depth.*
48 rds.	75 feet.
96 "	136 "
144 "	160 "
208 "	180 "
320 "	190 "
560 "	195 "
720 "	180 "
752 "	152 "
816 "	40 "
896 "	Shore.

From Sandstone to Sherwood Forest.

Distance.	*Depth.*
40 rds.	150 feet.
64 "	160 "
100 "	159 "
196 "	140 "
256 "	132 "
292 "	73 "
316 "	15 "
348 "	Shore.

From these tables and the profiles derived from them, it will be seen that the eastern part of the lake is comparatively shallow, and that there is a bar not far from the center where the depth is only twenty feet. The greatest depth — 195 feet — is reached between Sandstone Bluff and Sugar Loaf.

I have made no attempt at systematic soundings, but, in connection with dredging, have always taken the depth at the time of the haul, and my figures agree in all respects with those of Prof. Kenaston, except that they are uniformly somewhat less; this is easily explained by the fact that the level of the lake has been lower than usual for the past two or three years.

In the western part of the lake but few soundings have been made by any one. Capt. Pierce tells me that the greatest depth he has found is 172 feet. It is popularly supposed that the deepest place is between Sugar Loaf and the south shore, as that is the last place to freeze. I have found there, however, only 189 feet.

It will be noticed that the littoral zone, in most parts of the lake, is very narrow, considerable depths being reached quite near the shore.

When dredging in deep water, I also took surface and bottom temperatures. This work was done in Aug., Sept., and Oct. 1890, and July, 1891. As, so far as I know, very little work of this kind has been done in our lakes, I have thought the results worth recording, although my observations were too few to form a basis for any general inferences.

For bottom temperatures, I used a Miller-Casella deep sea thermometer, loaned by the United States Commissioner of Fish and Fisheries, and for surface temperatures a common chemical thermometer. As the thermometers were not tested, the results may not be absolutely accurate. The deep sea thermometer was attached about two meters from the sounding lead, giving the "bottom temperature."

The following tables give the temperatures arranged by depths:

AUGUST, 1890.

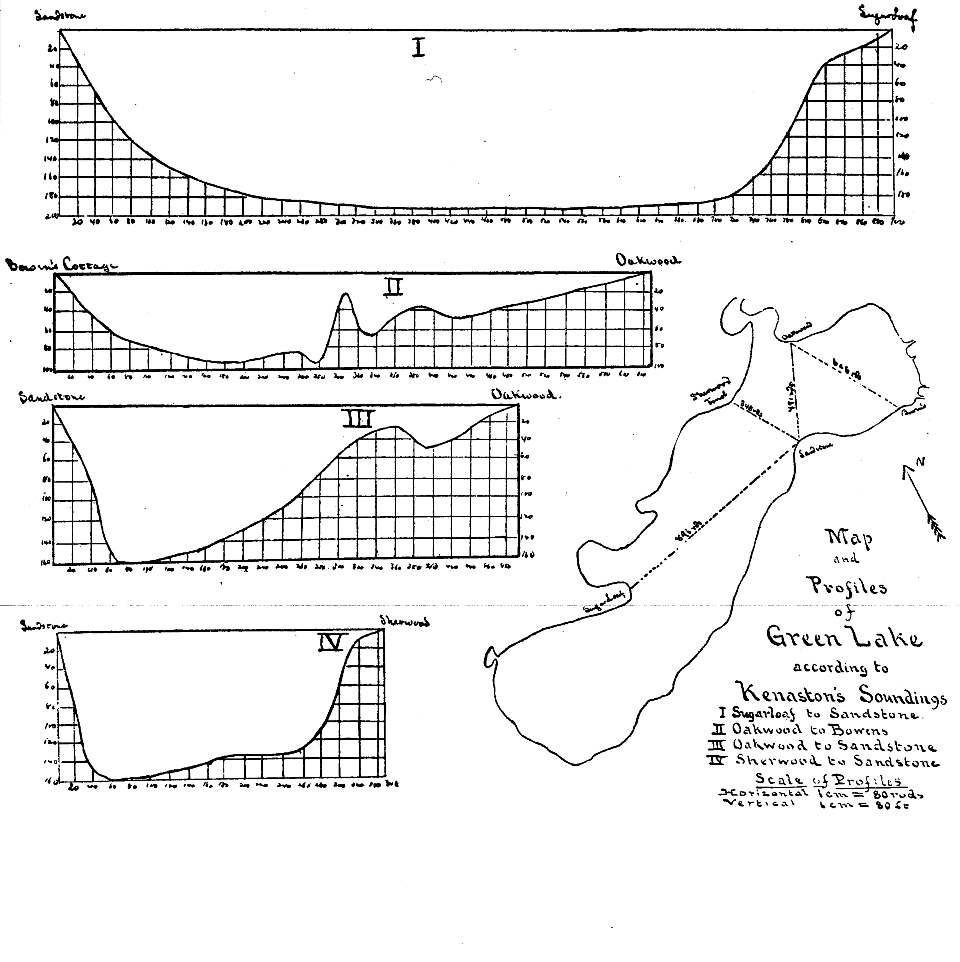
Depth.	Surface tem.	Bottom tem.
17 meters.	25° C.	10.25° C.
24.5	25.	7.7
31.	26.	7.45
33.	24.	7.2
36.	25.5	7.2
40.5	26.	7.
40.85	25.	7.
41.5	24.	7.
42.	24.5	7.
42.2	24.	7.
43.	24.	7.
45.25	....	6.6
46.75	24.	6.6
48.45	22.	6.6

JULY, 1891.

Depth.	Air tem.	Surface tem.	Bottom tem.
41.85 meters.	22°.77 C.	21.° C.	5.4° C.
43.5	23.33	23.	5.56
50.	22.22	22.	5.28
50.5	25.	22.	5.28
51.2	20.55	22.	5.28
56.	21.11	21.	5.28
57.75	24.72	21.	5.28
58.	26.3		5.28

We notice that in August, 1890, there was a uniform temperature of 6.6° C. below a depth of 45 meters, and that up to 25 meters there was an elevation of temperature of only one degree. In July, 1891, the bottom temperature was 5.28° C. While we cannot compare temperatures taken in August, 1890, with those taken in July, 1891, I think we may fairly infer that the maximum bottom temperature in Green Lake is reached in August, and that it remains nearly the same during September and October. The surface temperature is nearly the same in all the deeper parts of the lake. Swimmers, in crossing the lake, claim that they pass through "streaks" of different temperatures, but the thermometer determinations show a practical uniformity of surface temperature.

In comparing these temperatures with those obtained by Prof. and Mrs. Peckham in Pine Lake (Trans. Wis. Acad. V, 273), I notice that although the surface temperatures in Pine Lake, in both July and August, are higher than in Green Lake, the temperature of the deep water is nearly the same. For instance, in August, 1879, at a depth of 18.28 meters, the bottom temperature was 7.23° C., while the surface temperature at the same time was 24.44° C., and in July, at a depth of 24.38 meters, the bottom temperature was 5.56° C., and the surface temperature 26.12° C. Thus, at 24.38 meters, was reached very nearly the minimum temperature which I found in Green Lake at 50 meters and below.



Map
and
Profiles
of
Green Lake
according to
Kenaston's Soundings

I Sugarloaf to Sandstone.
II Oakwood to Bowens
III Oakwood to Sandstone
IV Sherwood to Sandstone

Scale of Profiles
Horizontal 1 cm = 80 rods
Vertical 1 cm = 80 ft

THE IRON ORES OF THE LAKE SUPERIOR REGION.

By C. R. VAN HISE.

The object of the present article is to bring together in a single paper the more important conclusions as to the iron ores of the Lake Superior region, which have been reached in recent years by the Lake Superior Division of the United States Geological Survey.

The iron ores are all associated with peculiar nonfragmental rocks which have great variety, but which have the common feature of containing a considerable content of iron. The varieties include ferruginous cherts, ferruginous slates, sideritic slates, actinolitic schists, magnetitic schists, hematitic schists and intermediate phases. At different times in the past it has been suggested that the Lake Superior iron ores, like many of those of later age, are derived from carbonate of iron. However, Irving was the first to definitely prove this by showing that in this region there is abundant residual iron carbonate, and that there are actual transitions between this and other phases of the iron formations.* Since this conclusion was announced, the evidence that these and also the ores are derived directly or indirectly from a lean cherty and often calcareous and magnesian siderite has been greatly augmented.

The manner of the transformation of the iron carbonates into the other phases of rock of the iron formation have been traced out in detail in the Penokee and Animikie districts.† The work of the past two years has given a large amount of evidence that exactly similar transformations have taken place in the Marquette, Vermilion, and Kaministiquia districts. As yet the Menominee proper and Felch Mountain districts have not been sufficiently studied to furnish this evidence; but the ferruginous rocks here occurring are exactly like those in the other districts and there is no doubt as to their equivalent age, so that it is highly probable that the same is true.

The iron ores now mined occur in two geological series, separated by a physical break.‡ These are the Lower Huronian and Upper Huronian.

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*Irving, R. D., Origin of the Ferruginous Schists and Iron Ores of the Lake Superior region: Am. Jour. Sci., 3rd ser., vol. 32, 1886, pp. 255–272.

†Irving, R. D. and Van Hise, C. R.: The Penokee Iron-Bearing Series of Michigan and Wisconsin: Tenth Ann. Rept. U. S. Geol. Survey, 1890, pp. 380-422.

‡Van Hise, C. R.: An attempt to harmonize some apparently conflicting Views of Lake Superior Stratigraphy. Am. Jour. Sci., 3rd ser., vol. 41, 1891, pp. 117-137.

In each there is one main iron-bearing formation both of which were originally of nearly the same character, and their subsequent transformations have been much alike. The chief differences are that hard specular hematite, magnetite, and the actinolite-magnetite-schists are more common in the older formation; while the soft hematites, limonites and cherts are more common in the newer formation. However, most phases of rocks and ores are found in both newer and older formations, the main difference being that of relative proportions.

As a consequence of the likeness of original characters and subsequent transformations it is possible to treat together the genesis of the ores of these two series.

A third horizon at which ore-bodies occur is at or near the base of the Upper Huronian. This formation is not continuous, it being present only when the base of the Upper Huronian chances to rest upon the iron-bearing formation of the Lower Huronian. Here the detritus has been largely derived from the immediately subjacent formation and is consequently rich in iron. As will be seen, a farther concentration of the iron oxides at this horizon has occurred at the same time as the concentration of the iron ores of the two main formations. At this third horizon are to be placed several of the important mines and certain of the ore-bodies of others of the mines of the Marquette district. The history of these deposits explains why they frequently occur adjacent to the ore-deposits of the Lower Huronian.

The Lower Huronian includes the Eastern Menominee, Felch Mountain, Lower Marquette, Vermilion, and Kaministiquia districts; and the Upper Huronian includes the Western Menominee, Upper Marquette, Penokee, Mesabi, and Animikie districts. It thus appears that in the Felch Mountain and Vermilion districts only the iron-bearing formation of the Lower Huronian is known, and in the Penokee and Mesabi districts only the iron-bearing formation of the Upper Huronian is known. In the Marquette and Menominee districts the iron formations of both series are represented, but the relations of the two are much more easily made out in the former than in the latter. The Kaministiquia and Animikie series also come together in a single district and the unconformable relations which here obtain are as clear as in the Marquette district.

As areas to serve as types we will first consider the Penokee and Lower Marquette series, the first belonging to the Upper Huronian and the second to the Lower Huronian. These are chosen because here the investigations have gone farther.

The Penokee ores.—In the Penokee district the iron-bearing formation comprising all the varieties of rocks above mentioned as belonging to this member, is on an average about 800 to 850 feet thick, but the iron ores are mainly confined to the lower 400 feet. The formation rests upon an argillaceous quartz-slate the uppermost horizon of which is a persistent quartzite. It is covered by a great formation of clay-slates, graywacke-slates, etc. These formations constituting the Penokee series are a simple monocline, dipping northward from 50° to 80° (Pl. VII, fig. 1.) The series has been cut before tilting by numerous basic dikes nearly at right angles to the bedding, but in such a direction as to now make the outcrops of a dike and the iron-bearing formation form the two sides of an acute angle which usually faces to the east. The unaltered phase of the iron-bearing formation, i. e., the lean cherty carbonate of iron, is most frequently found immediatly under the overlying slate, which has protected this material from percolating waters, while near its base rarely is found this sideritic phase, it having here usually been decomposed. The intersections of the dike rocks and the quartz-slates form numerous right angled troughs tilted somewhat to the northward, (Pl. VII, fig. 2.) These generally have a pitch toward the east (Pl. VII, fig. 3), consequent upon the relations already described. But if the outcrop of the dike is parallel to that of the ore formation the ore-deposit will have no pitch, while if the outcrops of the dike and quartz-slate form a westward-facing acute angle the deposit will have a pitch toward the west.

Now, with few exceptions, the ore-bodies of the entire Penokee district occur at the apices of these troughs (Pl. VII, figs. 2 and 3), having roughly a triangular section or a V shape the lower part of which is relatively heavy and pitching with the altered underlying diabase dikes, usually called by the miners "soapstone." The boundaries of the ore formation are usually sharp along the dike-rocks and the quartz-slate, but vary upward often by imperceptible stages into the ferruginous rocks of the iron-bearing formation. It follows from the above that each ore-deposit may be traced to the surface in one direction, and in the other direction will pass deeper and deeper. It is not uncommon for one dike some distance below another dike to also carry an ore-body. In this case a shaft will pass through its first ore-body, its basement dike and a greater or lesser thickness of lean ferruginous material, when another ore-body, resting upon another dike will be found (Pl. VII, fig. 3). This latter body may have been previously discovered at or near the surface at some point east or west of where the uppermost body reaches the surface and therefore ceases. In other cases the dikes may be so close together as to have the entire space between them filled with ore. In still other cases more than two dikes bearing ore-bodies have been found in vertical section.

Summing up, the Penokee ore-deposits are then roughly triangular in cross section. They usually pitch to the east. They rest upon impervious formations below, and generally grade upward into a porous ferruginous chert or slate of the iron formation.

The Lower Marquette Ores.—In the Lower Marquette * series the ores have somewhat greater variety of occurrence. The deposits, instead of

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* Van Hise, C. R. The Iron Ores of the Marquette district of Michigan. Am. Jour. Sci., 3d series, vol. 43, 1892, pp. 116–132.

being for the most part at the base of the iron-bearing formation, are either within this formation or at its upper part; that is, just below the base of the Upper Huronian. The formation above the iron-bearing formation is a quartzite grading downward into a conglomerate, the material of which, is largely derived from the subjacent Lower Huronian series. The iron-bearing formation is cut by numerous dikes at various inclinations and by great bosses of basic eruptives. These latter sometimes break across the bedding of the iron formation, at other times the intrusives bow the bedding upward so as to make the formation dip away from the greenstone ridges. Not in frequently a ridge of eruptives forms a more or less complete semicircle, the iron formation constituting a valley within it.

Now, the ore deposits are found either at the contact plane between the Upper and Lower Huronian, or else they rest upon or along the eruptives (Pl. VII, fig. 4); when fresh called diorite, when altered called soapstone. The dikes may be vertical or inclined. One may be alone or two or more may be adjacent. The greenstone bosses may have a uniform dip or may be folded so as to form a complete synclinal trough (Pl. VII, fig. 5). A dike may unite with a larger greenstone mass to form a trough (Pl. VII, fig. 6). Whether the ore deposit rests upon a wall, a synclinal or an irregular trough of eruptive rock, the body is not horizontal, but following the greenstone, pitches at an angle of 20° to 40° or even more. As in the Penokee district, the ore-deposits have an abrupt termination at the underlying eruptive rocks and grade upward somewhat gradually into the chert and jasper. In the case of those ore-deposits which are at the contact of the Upper and Lower Huronian, the bodies usually occur at places where the ore formation has been sharply shattered or bent; or where an intersecting intrusive serves as an inpervious basement; or where both are combined. Such deposits may terminate abruptly along a joint or may grade into the chert or jasper (Pl. VII, fig 7).

While the Marquette ore-deposits may rest upon formations of different characters, and may vary greatly in shape, in common with those of the Penokee district, they lie for the most part upon impervious formations in pitching troughs, and grade above into the broken aud porous material of the ore formation; or, if at the contact horizon, into the recomposed ore formation of the Upper Huronian.

Ores at base of Upper Marquette series.—The contact deposits of the Lower Huronian may continue upward into the Upper Huronian, a single ore-body belonging in part to the Lower Huronian and in part to the Upper Huronian, when the two series, although unconformable, are welded together by subsequent infiltrations, as a consequence of which the non-fragmental iron formation of the Lower Huronian appears to grade up into the mechanical sediments of the Upper Huronian. In other places the ore-deposits near the contact plane may lie wholly within the Lower Huronian or wholly within the Upper Huronian. In the latter case this may be sometimes due to the fact that erosion has removed all or nearly all of the Lower Huronian iron-bearing formation The ores above this contact plane, like those already considered, are frequently adjacent to or underlain by subsequent intrusives which serve as impervious basement formations.

The ores adjacent to the contact plane include the magnetites of the Marquette district. Those belonging to the Lower Huronian have a somewhat different aspect from those of the Upper Huronian. This is due to the extraneous mechanical detritus of the latter. In thin section it is often found that more or less mica has developed. In examining the structure of the ore-deposits, it is seen that much of the magnetite is in veins or cavities in finer grained and partly or wholly original material. An examination of thin sections of the overlying magnetic quartzites and conglomerates shows conclusively that much of the magnetite is a secondary infiltration.

Ores of other districts.— It is unnecessary to give the details of the occurrences of ores in other districts, but it may be said, while the character of the bounding formations may be somewhat different, that the ore-deposits as in the Penokee and in the Marquette districts rest upon formations which are impervious. These may be fragmental slates, contemporaneous surface volcanics, or subsequent intrusives. Also any one of these, or two of them, may combine to form a pitching trough. And even in the cases in which there is but a single impervious wall upon which the ore rests, it is usually found that the deposit has a pitch. The ore-bodies usually grade above into the other phases of rock of the iron-bearing formation, as in the Penokee and Marquette districts.

In the Western Menominee district the ore-bodies very extensively rest upon surface volcanics which appear to be here the inferior formation of the Upper Huronian series. In both the Upper Menominee and the Upper Marquette ores are also found resting upon the slates. In some cases these underlying slates have a monoclinal dip as in the Penokee district, and in others are folded into pitching synclinals. The iron-bearing horizons of these districts do not appear to be continuous belts of pure iron formation materials as is that of the Penokee. They are often but sideritic phases of the great slate formation of the Upper Huronian. Where this slate becomes usually sideritic and the other conditions explained as requisite occur together the concentration of ore-bodies has taken place.

In the Vermilion district the ore-bodies commonly rest upon impervious schists believed to be greatly modified volcanics or upon intrusive massive greenstones of later age. Not infrequently one or both of these combined form pitching troughs.

In the newly developed Mesabi range the ores, according to Mr. Merriam, are near the base of the series resting upon a quartzite which lies unconformably upon impervious green crystalline schists of the Archean complex. They are overlain by a slate or shale of great thickness. They have a gentle dip to the southward. In certain respects they are like the Penokee deposits. Whether the bodies will be found in pitching troughs, it is yet too early to say.

Genesis of the ores.— The peculiar forms and relations of the Lake Superior iron ores exclude a large number of explanations which have been advanced for the genesis of these deposits. It is evident that in their present position they are not eruptives. Even if it be argued that the iron-bearing formations are igneous it would hardly be held that these peculiar ore-bodies are of direct intrusive origin. The forms which these bodies have are wholly unlike those of intrusive rocks. Instead of being continuous downward as such rocks should be they usually terminate below upon igneous rocks. It is equally plain that the ore-deposits are not of direct sedimentary origin, although it is believed that the formations containing them, and from which they are derived are sedimentary. We know of no way by which sediments could be deposited in such irregular forms as these. Also their frequent connection with subsequent intrusive rocks shows that between the ore-deposits and the latter there is some genetic connection. Although by the miners the ores are often spoken of as veins, these deposits have never been seriously regarded as fissures, nor can they be regarded as deposits which have filled caves.

All of the evidence plainly points in one direction, that is, that they are concentrations produced by downward percolating water. These waters removed a part of the original material of the iron-bearing formations at the places where the ore-bodies occur and introduced iron oxide nearly simultaneously. This explains the forms, positions and relations of the ore-deposits. They rest upon tilted walls or troughs of impervious formations because water has here been converged. They occupy places once taken by a part of the ore-formation because this is readily penetrated by water, because it was rich in iron carbonate, and because the constituents other than iron oxide are readily soluble.

The original condition of the ore-formation, as has been said, is a lean sideritic and cherty slate. In order that the ore-bodies should be formed, silica must have been removed and iron oxide introduced. That this interchange has actually occurred is shown by an examination of the iron-formation rocks associated with the ore-bodies. It has been noted that the change from the ore-bodies to the rocks above is a transition rather than abrupt. Along this transition zone it is a common thing to see silica bands die out by gradual removal. In the iron formation proper the silica is frequently in nearly solid bands, alternating with bands richer in iron. In passing toward the ore, cavities appear in the rock, the silica being removed so that the stratum is here a porous one. The cellular or geodal cavities formed by the removal of silica are very characteristic of this transition zone and even when so minute as not to be visible in the hand specimen are discoverable by a microscopical examination. However, before all of the silica is removed, iron oxide begins to be introduced, and finally when the interchange is complete, in the places of the siliceous bands is a solid body of iron ore.

It is usually found that the eruptive rocks underlying the ore-bodies are greatly altered, the alkalies having been removed. It is probable that these alkalies have been an important agent in the solution of the adjacent silica. It is evident that the pitching troughs are places along which abundant water must travel because the surface waters are not able to penetrate the underlying formation, and the overlying formation is a porous one. It is equally evident that the contact plane between the Upper and Lower Huronian, where there is a coarse conglomerate at the base of the Upper Huronian, is also a horizon along which underground waters travel, and this is particularly true where violent folding has shattered the underlying ore-formation, and here it will be remembered the ore-bodies of this horizon usually occur.

Along these channels of percolation, as in the case of fissures, waters from various sources meet. A portion of these waters will have traveled for a considerable distance through the iron carbonates. Such waters will have oxidized this iron carbonate in part and thus become carbonated and take other iron carbonate into solution. Such iron-bearing waters will meet along the impervious formations other waters which have reached these positions by shorter paths, traveling perhaps wholly through already altered and brecciated ore-formation material containing no iron carbonate. Such waters carrying no iron, but containing oxygen, will precipitate the iron from the carbonated solutions.

Those ore-bodies which underlie one or more impervious formations, but rest upon other impervious formations have derived their material from the areas of iron formation material between the dike or other basement formations of the ore-bodies in question and those of the next overlying deposit. In a given instance this part of the ore-formation will have a considerable surface area for the entrance of percolating waters between the outcrops of the underlying and overlying impervious formations. (See Plate VII, fig. 3.) The waters have here carried the iron oxide along the impervious formation upon which the ore rests and have precipitated it under the overlying impervious body. Whether the ore-body thus produced fills the entire space between the two impervious formations depends upon the supply of material which was available and upon the perfection with which the process of concentration has been carried out.

In the production of the magnetic ores it appears that there was not a sufficient amount of oxygen to peroxidize the iron, although there was enough to precipitate it or a part of it at least. Pyrite associated with the magnetite indicates the presence of actual reducing agents and these may have changed some of the original hematite of this horizon to the form of magnetite. This lack of oxygen at the plane separating the Lower and Upper Huronian may be due to the fact that immediately above is the impervious slate of the latter; consequently from the surface there was no direct path for percolating waters.

From what has been said as to the transition zone between the ore-bodies and the iron formation, it will be seen that the process of the solution of the silica often runs in advance of the introduction of the iron oxide. It is wholly possible that the silica has been sometimes removed so far ahead as to cause a considerable sagging of the ore-formation. This suggestion is made because the brecciated character of the rocks adjacent to the ore-bodies frequently indicates that local fractures have occurred.

Many of the intrusives which cut the ore-formations are probably of Keweenawan age. If this be true it is evident that the concentration of these ore-deposits has occurred since Keweenawan time. It is also manifest that the final concentration did not occur until the folding and erosion subsequent to both the Lower and Upper Huronian series, and for a part of the districts at least these were post-Keweenawan. It is almost certain that the Lower Huronian iron formation was extensively modified before the Upper Huronian series was deposited, but it is also probable that the ore-bodies now mined have been produced simultaneously with those of the Upper Huronian, otherwise the Lower Huronian ore-deposits would not invariably be found above the eruptive rocks with which they are in contact. While the final concentration did not begin until the later foldings to which these series have been subjected, there is no evidence that the process has ceased at the present time.

The ore-bodies at the base of the Upper Huronian were concentrated in the lean detritus of the Lower Huronian iron formation at the same time and in the same manner as the ore-deposits just considered.

The remarkable likeness of the Upper and Lower Huronian ore-formations is then explained to be due to the likeness of the original iron-bearing formations of the Upper and Lower Huronian, and to the fact that the concentration of both was due to the same causes operating at the same time.

The Huronian rocks of Lake Superior are often spoken of as the iron-bearing series. The foregoing discussion shows that ore-bodies occur only in certain definite formations which constitute but a small percentage of the entire Huronian series. Moreover it is evident that valuable ores are only found within these formations where a combination of peculiar conditions occur causing local concentrations of iron oxide. A recognition on the part of practical mining men of these principles will save large sums of money annually spent in unscientific prospecting, and, as they have already done in certain cases, will undoubtedly lead to the discovery of additional ore-bodies.

U. S. Geological Survey,
Lake Superior Division,
MADISON, WIS., March 7, 1892.

DESCRIPTION OF PLATE VII.

Fig. 1. Cross-section of Penokee series. Showing its relations to the underlying Archean, the overlying Keweenawan, and the conformable succession of its three members.

Fig. 2. Cross-section of Pence mine, Penokee series, showing the relations of the dike-rock, quartzite, ore-deposit, and drift material.

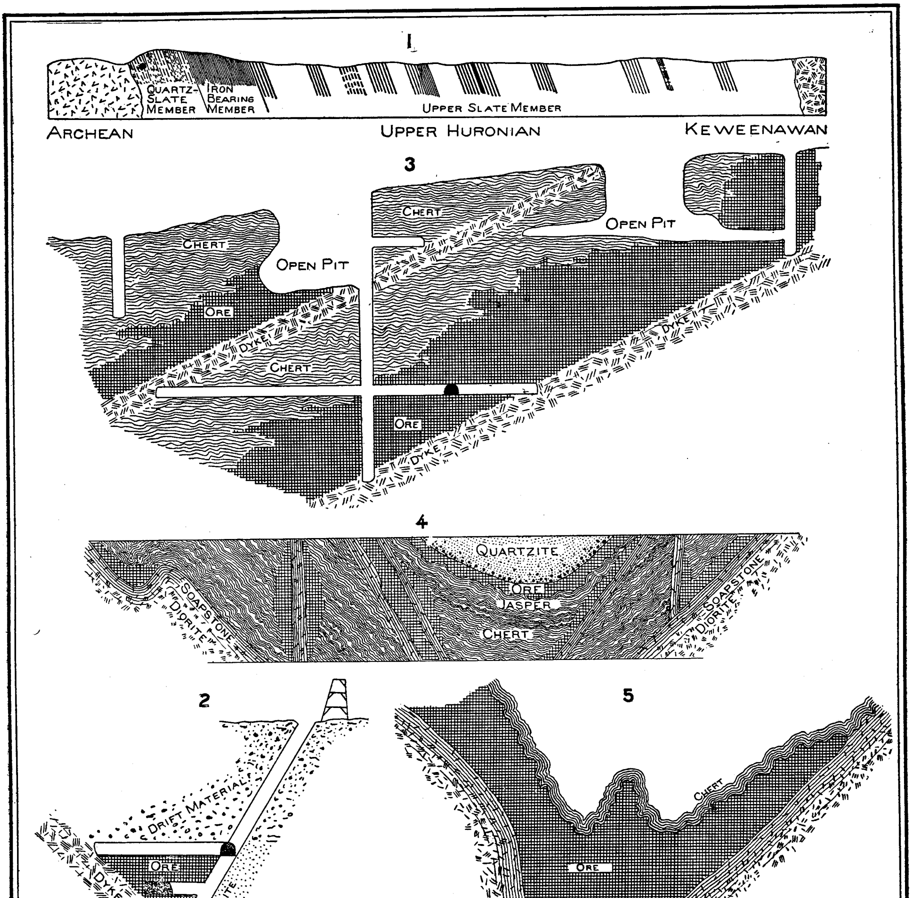
Fig. 3. Longitudinal section of a Penokee deposit, looking south. The figure shows how, as a consequence of the pitch of the dikes, the ore-bodies which reach the rock surface soon pass under the furruginous chert. The figure also shows, when one dike is parallel to another or nearly so, that the ore-body of the lower dike may pass under that of the upper. The vertical distance between the two deposits depends upon the horizontal distance between the outcrop of the two dikes and upon their pitch. The irregular way in which the ore passes above into the chert is seen, as well as a horse of rock at the west end of the west open pit.

Fig. 4. Generalized section of Lower Marquette ores, showing the relations of the deposits to the associated formations. Ore is seen at the contact of the Upper and Lower Huronion, above a folded mass of diorite, upon one or both sides of intersecting dikes, and in a trough formed by the union of a dike and a mass of diorite.

Fig. 5. Vertical cross-section of an ore-deposit of the Marquette district. This is bounded below by a synclinal of soapstone grading into diorite and above by ferruginous chert. The change from ore to chert is not so sharp as drawn. In longitudinal section this body shows a considerable pitch.

Fig. 6. Vertical cross-section of an ore-deposit of Marquette district. At the left the ore rests upon soapstone grading into diorite. At the right it is upon one side of a dike-rock, the latter being an off-shoot of the diorite. At the contact of the two a pitching trough is formed in which the ore-body becomes of large size.

Fig. 7. Horizontal section of ore-deposit on east side of Republic horse-shoe, Marquette district. The left side of the ore is bounded by a cross joint. The right side is bounded in part by a sharp flexure passing into a joint, and in part grades into the lean banded jasper and ore.



ORE DEPOSITS of LAKE SUPERIOR REGION

THE PRESENT CONDITION OF THE LATITUDE PROBLEM.

BY G. C. COMSTOCK.

[ABSTRACT.]

The title which has been announced for my paper, "The Present Condition of the Latitude Problem," imposes upon me the necessity of explaining in what the latitude problem consists, since I can not assume that the term thus employed will be well understood even in scientific circles.

There come down to us from remote antiquity legends, curious enough in themselves, which seem to imply that at the time of their origin a very different condition of affairs obtained from that which now exists. Thus the early Egyptian temples appear to have been oriented with reference to the points of the compass at times when those points were different from what they now are, and there are traditions of a time at which the sun rose in the west and set in the east. And coming down to much more recent dates, speculation has been rife as to whether the great pyramids in Egypt may not contain in themselves evidence of a changed position of the earth's rotation axis.

Until within the last half dozen years such matters were looked upon by astronomers with the utmost incredulity, and it was almost a matter of faith that the earth's axis is the one thing terrestrial which is permanent in position. But about a half dozen years since Dr. Kuestner, one of the astronomers connected with the observatory at Berlin, undertook a very extended and accurate series of latitude determinations at that place, having in view as the object to be attained the solution of a very different problem, the determination of the so-called "constant of aberration." But Kuestner's results for the aberration came out wrong; they would not agree with the classical values of this quantity elsewhere determined, and he found himself face to face with the alternatives that either his observations were hopelessly bad, or that the latitude of his observatory had changed to the amount of nearly half a second during the time covered by his observations. Kuestner adopted the latter alternative, but his suggestions were received with great incredulity on the part of astronomers, and it was only when it became apparent that similar changes could be traced in simultaneous observations elsewhere that the matter seemed worthy of serious investigation. Such investigation it has received under the auspices of the International Geodetic Association, which has for over two years past maintained a continuous series of observations at three German observatories, which agree in indicating a variation of the latitude of these stations in character entirely similar to that detected by Kuestner. In our own country similar investigations have been prosecuted in a less systematic manner, but agreeing nevertheless with the results of the German work.

But we come here to a new phase of the matter. An extended and very elaborate discussion of long series of astronomical observations running back over a period of more than a century has been undertaken by Mr. S. C. Chandler, who has reached the very remarkable result that during this entire period traces of a similar variation in latitudes may be detected, that is, that during this period the latitude of any given place on the earth's surface, instead of being absolutely fixed, has oscillated about a mean value, being at times a little greater and at others a little less than its average amount.

If we inquire into the causes of such an instability of latitude, we shall find very serious difficulties in the way of any explanation based upon known dynamical laws. It is true that Euler pointed out a century ago that if the axis about which the earth rotates does not coincide exactly with its axis of figure, that is the short diameter of the spheroidal earth, there will necessarily result a rotation of one of these axes about the other producing a slight periodic change in latitudes, and that this change should run through its complete cycle in a period of 306 days But it seems difficult at first sight to identify this theoretical oscillation with the actual changes detected by the European observers and by Mr. Chandler. The work of the European observers appeared to indicate an oscillation of latitudes having a period of very approximately a year, while the time required for the periodic change detected by Chandler is 427 days; so that the periods appear to be entirely discordant. A suggestion has been made in this connection, however, by Professor Newcomb which may help to bridge over the difficulty of co-ordinating these periods among themselves. He points out that the period of 306 days which is associated with Euler's name has been computed upon the supposition that the earth is a perfectly rigid body, while we have abundant evidence that the earth's rigidity, although great, is by no means infinite, and this lack of perfect rigidity will have the effect of lengthening the Euler period, so that it may be made 365 days or 427 days long, thus possibly bringing it into agreement with the observed periods. One difficulty however, stands in the way of this explanation. Mr. Chandler has indicated as a result of his investigation that the period of time within which the latitude makes a complete oscillation is not of uniform length but ranges from about 350 up to 427 days, and this variation in the length of the period is in no way accounted for by Newcomb's explanation.

Turning now for a moment aside from this periodic variation of the latitude, let us briefly consider another but allied phase of the same matter. At the conference of the International Geodetic Association, held at Rome in 1884, Fergola, an Italian astronomer, presented a considerable amount of data tending to show that during the past century there had been a progressive diminution in the latitudes of European observatories. In other words, that aside from this periodic variation of latitudes there had been a steady and uniform drift of the surface of the earth in Europe away from the north pole. Fergola's paper attracted great interest at the time, and his suggestion that a concerted plan of action should be adopted for the systematic investigation of this secular change in latitude was adopted by the Geodetic Association. Measures were taken to have a series of observations for this purpose commenced at Washington and at Lisbon; but unfortunately the matter terminated without anything having been accomplished and the plan for systematic investigation seems to have been abandoned.

At the earnest request of some geologists especially interested in glacial phenomena, I took up the question of the secular variation of latitudes anew some three years ago, with the intention of examining more carefully the American data, which had scarcely been touched upon by Fergola, and of ascertaining whether it could be made to yield any contribution to a better knowledge of the secular change. Without going into the details of this investigation, it may suffice to state here that this data, although somewhat scanty in amount, still indicates very strongly that American observatories have a common motion toward the north pole amounting to about four feet per year; in other words, that the rotation axis of the earth, instead of being fixed relatively to the crust of the earth, is changing its position, moving in a direction along the west coast of Greenland, so that it is being brought progressively nearer to American stations and carried more slowly away from European ones. The results of this investigation were presented last summer to the American Association for the Advancement of Science, and a committee of that association was appointed to devise means for further investigation of these changes in latitude, both periodic and secular. Under the auspices of the International Geodetic Association, simultaneous observations are now being made in Germany and in the Hawaiian Islands. These will suffice for a very accurate determination of the periodic changes of latitude, but they are not well adapted to a determination of the secular change, the longitudes being badly chosen for this purpose, and it is very much to be desired that as soon as possible a series of observations having the secular change in view should be undertaken in the United States and along the eastern coast of Asia, since the direction of the motion of the pole appears to be such that stations thus located will be subject to larger variations of latitude than those in any other longitudes.

ON THE CORRELATION OF MORAINES WITH RAISED BEACHES OF LAKE ERIE.*

BY FRANK LEVERETT.

The narrow ridges of sand and gravel which traverse the plains of the western Erie basin, at distances varying from a few miles up to 80 miles or more from the present shore of Lake Erie, as well as those of the eastern portion of the Lake Erie basin, which lie near the borders of the lake, were recognized by the early settlers as old lake shores, and were known in many sections as "lake ridges." Nearly all the reports of geologists, whose work has lain within the territory covered by these beach lines, contain references to the beaches, and many contain valuable data concerning them, but so far as I am aware no complete tracing of any one of the beaches has been made by my predecessors.

At the time the reports of the Ohio geological survey were written, the question seems not to have been raised as to whether the beaches completely encircle the lake, though Dr. Newberry and Prof. Winchell each entertained the hypothesis that the high stage of water in the lake may have been caused by the occupancy of the present outlet of the Great Lakes by the retreating ice-sheet.† During the twenty years that have elapsed since these reports appeared, critical investigation of certain districts has shown that these beaches do not in all cases surround the bodies of water which they border. To Mr. Gilbert especially are we indebted for the advancement of knowledge along this line. The discovery was made by him, some years ago, that several of the raised beaches of Lake Erie do not completely encircle that body of water, but that those along its south shore terminate in a successive series from higher to lower in passing eastward from northern Ohio to southwestern New York. The results of his study are unpublished, but through his kindness I have been made acquainted with his recent views and supplied with the principal data. In explanation of the failure or disappearance of these beaches, in the eastern portion of the basin, Mr. Gilbert has entertained the theory that their eastern termini represent suc-

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* The article from which the main part of this paper is taken appears in full in the American Journal of Science, Vol. XLIII, April, 1892.

† Geology of Ohio, Vol. I., p. 552; Proc. Amer. Ass. Adv. Sci., 1872, p. 183.

cessive positions of the ice front in its northeastward retreat across the Lake Erie basin, but has held that the complete verification of this theory depends upon the occurrence of moraines which are the demonstrable correlatives of the beaches. It is believed that such moraines have now been discovered and traced into connection with the three beaches which terminate in Ohio. Two other beaches terminate in southwestern New York, but since the glacial phenomena of that region have not received critical attention, it is not known whether moraines occur there which can be correlated with the beaches. The limitations of the several stages of the lake, on its north shore, have not been determined. The study is, therefore, far from complete and the present paper furnishes but a brief introduction to the interesting history which further investigations promise to reveal.

The facts to be presented are naturally grouped under three heads: (I) The Van Wert or Upper beach and its correlative moraine, the Blanchard ridge; (II) The Leipsic or second beach and its correlative moraine; (III) The Belmore, or third beach and its correlative moraine. The names here adopted are those suggested by Prof. N. H. Winchell.*

I. THE VAN WERT OR UPPER BEACH AND ITS CORRELATIVE MORAINE.

(a) *The Van Wert or Upper Beach.*—The distribution of this beach in Ohio and Indiana, and the southwestward outlet of the lake which it bordered, are well shown in maps published many years ago by Mr Gilbert.† It was supposed by Mr. Gilbert, at that time, that the beach continued further east than Findlay, and his maps accordingly contain a hypothetical continuation along the north slope of the Blanchard moraine to the Sandusky river at Tiffin. It is now found that there is a beach line having about the position conjectured by Mr. Gilbert, but it is the Leipsic or second beach, while the Van Wert or upper beach apparently terminates at Findlay, there being in the district east from the meridian of Findlay no beach line outside (south) of the Leipsic beach. At its eastern terminus, the beach is in the midst of a plain that rises gradually toward the north, the east, and the south, so that the lake terminated in a mere point whose waters were quite shallow. Along the Blanchard moraine, on the north side of of the river, there is no beach line of corresponding age with the Van Wert ridge, though sand sets in on the outer slope a short distance west from Findlay and reaches altitudes as great as on the beach south of the river. The phenomena along the moraine, as shown below, seem to indicate that the ice-sheet overhung it while the lake was still occupying the Van Wert beach, and thus prevented the waves of the glacial lake from making their impress on the moraine.

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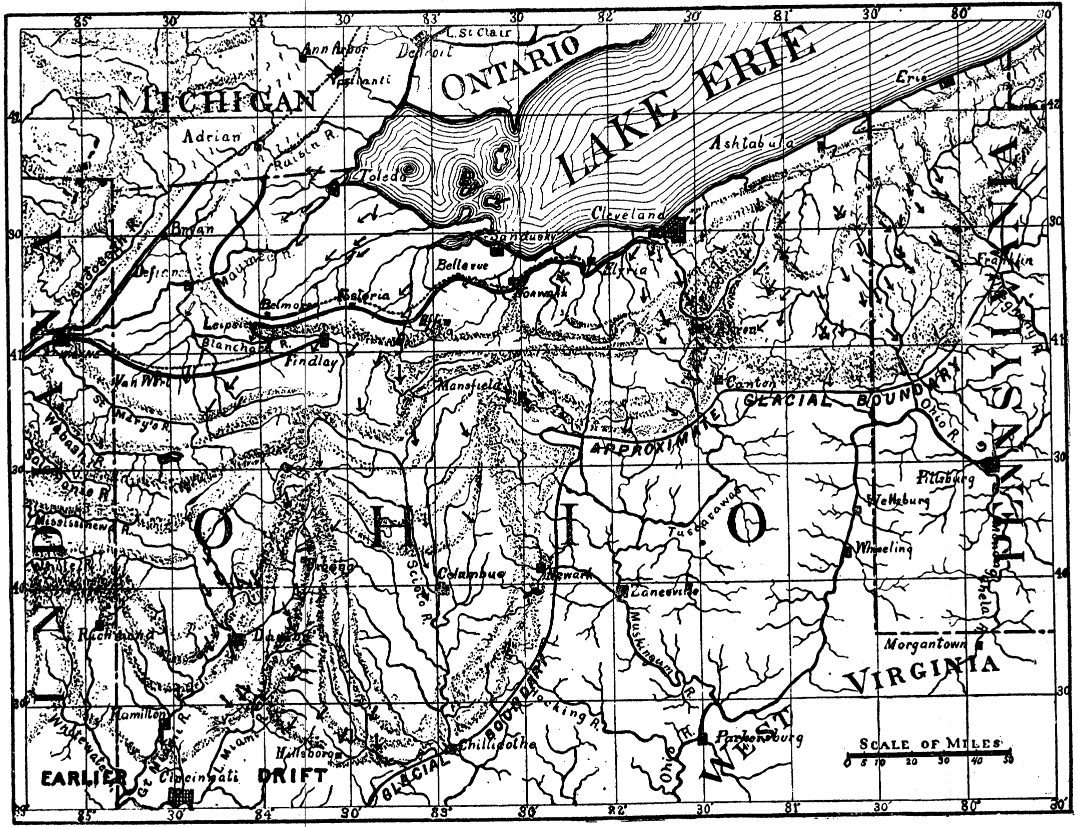
* Proc. Am. Ass. Adv. Sci. 1872, pp. 171–179. Geol. of Ohio, Vol. II., p. 56.

†Am. Journ. of Science, May 1871, p. 341. Geol. of Ohio, Vol. I. 1873, p. 540.



Map of the Western Erie Basin and adjacent territory. By Frank Leverett.

Explanation of Map.—The shaded portions represent moraines. Beach lines completely traced are represented by continuous lines, those incompletely traced by broken lines. Strias are indicated by arrows.

The altitude of the Van Wert beach throughout its course in Indiana and Ohio, has a variation of scarcely ten feet, the general altitude being very nearly 210 feet above Lake Erie. In Michigan it has been examined by Dr. J. W. Spencer, who reports a marked northward differential uplift between Ypsilanti and Berville, its altitude being 211 feet at Ypsilanti, and 244 feet at Berville.*

The Van Wert ridge, so far as I have examined it, consists in the main of a deposit of sandy gravel. It is not a strong beach, its usual height being three to five feet and its breadth but ten to twelve rods. Its pebbles are often but slightly worn, an indication that wave action was not strong. It is not improbable that throughout a larger portion of the year than at present the lake shore was fringed by ice. Fossils are extremely rare if not entirely absent from this beach, a feature which accords well with the view that the beach was formed during the low temperature of the glacial period, though it is merely negative evidence, since the absence or scarcity of fossils is not always due to the original absence of life, but often to the lack of conditions for preservation.

(b) *The Blanchard Moraine.*—The Blanchard is the latest moraine of the series in Ohio, that can be traced around the western end of Lake Erie. Westward from Findlay the moraine, though a less conspicuous feature than eastward from that city, was recognized and mapped by Mr. Gilbert more than twenty years ago.† It is, therefore, one of the earliest recognized moraines on this continent. From near the meridian of Findlay eastward it resembles the earlier moraines in presenting a broadly ridged and slightly undulatory tract of till, standing twenty to forty feet above the plain south of it, and having a breadth of one and one-half to three miles. Near the meridian referred to it assumes a very different appearance, that of a knob and basin topography of subdued type in which knolls of conical form rise abruptly five to ten feet and cover an acre or less each, and among which are sharp basins occupying usually but a small fraction of an acre each, though frequently several feet in depth. The crest of the moraine is no longer well defined though it continues to be a water shed-between tributaries of the Maumee, all the way to that stream near Defiance.

The structure presents as marked a change as the topography. Instead of a uniform deposit of till at the surface, there is a variety of formations remarkable for the abruptness of their alternations. In one knoll a fine sand may occur while its neighbors are composed of clay, or a portion of a knoll may be sand and the remainder clay, the whole being moulded together in a symmetrical knoll, like the gravel and till in ordinary kames. A few knolls contain gravel but as a rule pebbles are rare, and no surface bowlders or large pebbles were observed. The clays are very calcareous and abound in nodules in nearly every exposure.

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* Am. Journ. Sci. March 1891.

† Am. Journ. Sci., May 1, 1871, pp. 339–342.

Such is the character of the moraine for a distance of ten or twelve miles. About three miles northwest of Leipsic, near the center of township 2 north, range 7 east, the Leipsic or second beach crosses the moraine, and from there northwestward the moraine has a comparatively smooth surface, the result of wave action subsequent to the retreat of the ice.

The portion of the moraine of especial interest is the knob and basin tract, above described. If my interpretation be correct this owes its peculiar topography and structure to the presence of lake water beneath the ice-margin. This portion of the moraine has an altitude but slightly below the level of the Van Wert Beach, consequently the water was shallow and incapable of buoying up the ice-sheet and producing icebergs. The result was what might be anticipated under such conditions of deposition, a variable structure produced by the motion of water under the edge of the melting ice-sheet, and an uneven surface moulded by the inequalities of its base and margin. It may be suggested that the moraine received its sandy deposits from a lake that covered it after the ice had retreated. It seems improbable, however, that such was the case, (1) because the sandy deposits are not in the form of a beach nor in any way connected with a well defined beach, but consist of sharp knolls similar to the clay knolls of the moraine; (2) because the sand in places graduates into clay of glacial origin showing contemporaneous deposition with it; (3) because the basins and depressions are so sharp and of such a form and arrangement as to forbid the idea that wave action was long exerted on them; (4) the portion of the moraine northwestward from where the Leipsic beach crosses, affords a clear illustration of the effect of an open lake on the moraine, its surface being smooth and its sand either a uniform coating or aggregated into forms clearly referable to wave or wind action. It is fortunate that the lake in its later stages fell short a few feet of reaching its earlier maximum stage, and thus left unmodified a portion of what appears to be a lake-deposited moraine. So far as I am aware no case of a moraine demonstrably formed in lake water has been reported from other parts of the glaciated district, but it is not improbable that other instances will be found when attention is directed more closely to the subject, if they have not already been observed by other students. It is quite probable that in portions of this moraine further north there will be found other places similar to that described.

Summing up the phenomena of this district it appears, (1) that the Van Wert ridge terminates near Findlay, Ohio, and that east from there the Blanchard moraine is its correlative, (2) that the Blanchard moraine from near the line of Putnam and Hancock counties northward was deposited in lake water. The beach as well as the morainic phenomena, therefore, support the hypothesis that the lake bounded by the Van Wert beach was of *glacial* age.

II. THE LEIPSIC OR SECOND BEACH AND ITS CORRELATIVE MORAINE.

(a) *The Leipsic or Second Beach.*—This beach was traced from the Blanchard river, near Ottawa, eastward to its eastern terminus near Cleveland. Its course is not known west from the meridian of Ottawa, but it is probably the correlative of Mr. Gilbert's "Second Beach" that passes through Bryan and Hicksville, Ohio, since it has about the same altitude as that beach, and since no other beach that could be a correlative has been found.

In the portion already traced the course of the beach is winding, following pretty closely a contour line 195 to 200 feet above the lake, though for a portion of its course, lying between the villages of Van Buren and Bellevue, it has an altitude about 210 feet above the lake.

From the Blanchard river, at a point about three miles above Ottawa, it passes northwestward along the outer face of the Blanchard moraine for a distance of 9 to 10 miles. Here it crosses the moraine and passes south of east along its inner face for a few miles. It then leaves the moraine to the south and takes a course north of east, through McComb and Van Buren, to Fostoria. From Fostoria it bears south of east through Bascom to the Sandusky river at Tiffin, then northeast to Bellevue, southeast to the Huron river, near Pontiac, northeast again nearly to Elyria, then south a few miles to Black river, after which it takes nearly a direct course toward its eastern terminus near Cleveland. The bays at Sandusky, Huron and Black rivers, were not formed by the cutting back of the shore of the lake, for a restoration of the original slope on which the shore was carved, shows that the lake nowhere cut back its shore a mile, and usually but a few rods. The general appearance of this beach is much like that of the Van Vert, though it is on the whole somewhat stronger, its wave cut benches standing often 6 to 8 feet, and occasionally 15 to 20 feet, above the inner border plain. Its gravels like those of the Van Wert beach contain many pebbles which are but slightly rounded, and there are many places where bowlders are imbedded in the beach deposits. The only fossils discovered are the horns of elk and deer which were obtained in a railway gravel pit three miles east of Ottawa, from undisturbed gravel at a depth of 7 to 9 feet from the surface. All the evidence collected favors the view that the shore throughout a large portion of the year was protected by ice from the action of the waves.

As previously stated the Leipsic beach has its terminus near Cleveland. The beach here connects with the western end of a moraine. Between Rockport and Linndale the beach swings from a course north of east, to a southerly course, and is there made up of a series of ridges of nearly uniform height, which are united at the curving portion of the ridge, but diverge into distinct ridges toward the southeast, so that their ends are spread out over a space of nearly one-half mile. The outer ridge comes to Big Creek bluff in North Linndale. There is outside of these beach ridges a peculiar ridge, which appears to be a compromise between a beach and a moraine. At its western end, near the inner bend of a tributary of Big Creek, a mile or so west of North Linndale, it is composed of gravel, and resembles in every way the beaches just north of it, but upon tracing it eastward the gravel changes to till, giving it the appearance of a low glacial ridge. This low till ridge may be traced through North Linndale to the bluff of Big Creek, near the bend of that stream, and upon crossing the creek we find a much larger ridge of till, one worthy the name moraine. This larger ridge is separated from the eastern end of the beach proper by the narrow valley of Big Creek, one-fourth mile or less in width. I was unable to find beach gravel along the inner (north) slope of the morainic ridge, further east than the terminus of the beach ridge, but this inner border district is very flat, and its clays contain few pebbles compared with the clays of the moraine. These features apparently indicate that the lake water covered the tract north of the moraine, either while the ice overhung it or subsequently.

(b) *The Correlative Moraine of the Leipsic Beach.*— This moraine as indicated above, is traceable no further west than North Linndale. Both north and west from there the surface, aside from the low beaches, is a monotonous plain with scarcely any undulation. The disappearance of the moraine at the point where the beach appears, leaves little room for doubt that the ice-sheet here terminated in a lake, and that the beach is of glacial age. The portion of the moraine west of the Cuyahoga does not show evidence that it was deposited in lake water. On the contrary, its structure, so far as exposed, opposes such a theory of deposition, the mass of the ridge being ordinary till without capping of sand or other water deposits. The descent is rapid toward the Lake Erie basin from the junction of the beach and moraine; there was probably sufficient depth of water to cause the ice-sheet to break up into bergs at its margin instead of resting on the lake bottom and forming such a moraine as it did in the western Erie basin, northward from the junction of the Van Wert beach and Blanchard moraine.

Tracing the moraine eastward we find it passing just south of the village of Brighton, near which it is interrupted by the Cuyahoga valley. It reappears on the east side of the river in Newburg and is traceable from there eastward, through Randall and Warrensville to the Chagrin river below Chagrin Falls. West of the Cuyahoga it is a single gently undulating ridge, about 80 rods in width and 20 to 30 feet in height. East of the river it consists of many short ridges and conical swells 10 to 25 feet in height and has a width of one to two miles or more. In places there is a well defined crest, but as a rule the crest is wanting.

The range of altitude is considerable. West of the Cuyahoga the moraine stands about 800 feet A. T. East of the river it rises from 800 feet at Newburg to 1,050 feet at Randall (only six miles distant), and ranges up and down 200 to 250 feet in eastern Cuyahoga and Geauga counties in crossing ridges and valleys, its highest points being about 1,250 feet A. T.

The thickness of drift as shown by its relief above border districts is only twenty to thirty feet, but spread out as it is over a width of one to two miles, it represents an accumulation at least 100 times that of the correlative beach. The moraine is composed principally of till, though in places it has gravelly knolls (kames). Pockets of gravel and sand occur in the till, and beds of assorted material are occasionally interstratified with it. In short, the moraine in its topography, range in altitude, bulk and constitution, is so different from the beach that the two formations cannot be confused, and yet there seems to be no question that the moraine of the eastern Erie basin has, in the western Erie basin, a beach for its correlative.

III. THE BELMORE BEACH AND ITS CORRELATIVE MORAINE.

Between the Leipsic beach and the present shore of Lake Erie, there are several beaches. One of these, the Belmore beach, terminates near Cleveland, the others continue eastward into southwestern New York, and do not concern us in the present discussion. From its eastern terminus westward to the meridian of Belmore and Leipsic, the Belmore beach lies only one to three miles and in places, as at Berlin Heights, only a few rods north of the Leipsic beach. Westward from this meridian the courses of the two beaches are quite divergent, the Leipsic bearing south of west, while the Belmore bears northwestward crossing the Maumee river near Defiance, from which stream it bears east of north into Michigan. The general altitude of the Belmore beach within the state of Ohio is 160 to 170 feet above Lake Erie. It lies, therefore, too low to open southwestward, as do the earlier beaches, through the Ft. Wayne outlet.

In size and general appearance this beach differs but little from the Leipsic, but is on the whole more sandy.

The ridge phase of the Belmore beach apparently exists no further east than the Cuyahoga river but it is thought that the lower of the two terraces in the eastern part of Cleveland was occupied by the lake at the time this beach was forming. The absence of a beach, in the eastern Erie basin, which could be considered a correlative of the Belmore beach, has been determined by Mr. Gilbert, we therefore are led to inquire whether a moraine occurs there as a correlative of the beach.

The innermost moraine formed on the southern borders of the Lake Erie basin, is distinctly traceable from the eastern end of the lake, westward to Euclid, Ohio, a village situated about ten miles east from the mouth of the Cuyahoga. The gap between the western end of the moraine and the eastern end of the ridge phase of the Belmore beach, is, therefore, about ten miles, but between the moraine and the Cleveland terrace it is scarcely half that distance, and I am not certain but that the terrace may find occasional development along the face of the bold escarpment south of Lake Erie, as far east as the western terminus of the moraine. But should the gap between the moraine and the beach prove to be five or even ten miles, it would not follow that they cannot be correlated with each other, for the position of the boundary between the ice-sheet and the lake may have oscillated through a distance as great as this gap, during the course of the period in which the moraine and beach were forming. The failure or disappearance of the beach necessitates an explanation, and the only probable one yet found, is that the ice-sheet excluded the lake from the eastern portion of the basin, and the disappearance of this moraine near the eastern end of the beach, though it does not connect as closely with the beach as do earlier moraines with their correlative beaches, leaves no reasonable room for doubt that it is the correlative of the Belmore beach.

SUMMARY AND CONCLUSIONS.

From the data above presented it appears that Lake Erie in its earlier stages was but a small body of water, its size being conditional on the position of the retreating ice-sheet, and the height of the western rim of the basin it occupied. It at first occupied only a portion of the district between the outlet and the western end of the present lake, the remainder of the basin, including the whole of the area of the present lake, being occupied by the ice-sheet. Its south and north shores were then at the Van Wert ridge, while its eastern border was at the Blanchard moraine. At the time of the formation of the Leipsic and Belmore beaches the area of the lake was nearly as great as the present area of Lake Erie, though it occupied but little of the present bed of the lake.

From the phenomena attending the replacement of the three beaches in Ohio by moraines, we are led to suspect that the two later beaches which die away in southwestern New York are there connected with moraines, and that similar moraines will be found to connect with the beaches of Lake Ontario at points where they disappear on its eastern and northern borders.

Differential uplift was slight in the western Erie basin compared with what it was in the eastern Erie basin and the Ontario, and on the shores of Lake Huron and Georgian Bay. The data at hand indicate that it amounts to scarcely more than ten feet in the whole area of the portion of the Erie basin west of Cleveland, and has therefore played an insignificant part in causing the three stages of the lake herein described.

The bulk of the moraines is many times that of the beach deposits, though no longer time was involved in their deposition. The ice-sheet was, therefore, a much more efficient transporting agency than the lake waves.

The extreme scarcity of evidence of life in these waters is a feature quite accordant with the theory deduced from the relation of the beaches to the moraines, that the lake was of glacial age.

THE CUNEIFORM INSCRIPTIONS ON THE MONUMENTS OF THE ACHÆMENIDES*

TRANSLATED BY

HERBERT CUSHING TOLMAN, PH. D.

THE SEPULCHRAL INSCRIPTION OF CYRUS.

The oldest inscription of Persia is found on that structure generally believed to be the tomb of Cyrus. At Pasargadae, in the midst of the plain of Murghab, stands a building of white marble rising to the height of thirty-six feet from the ground. Its base is forty-seven feet long and forty-four feet broad. A figure in bas-relief carved on a pillar, perhaps the portrait of the king himself, strengthens the theory that this structure is the tomb of Cyrus. A narrow doorway leads into an inner chamber, where Arrian says, the body of Cyrus was placed. Under the relief is the cuneiform inscription, the translation of which follows:

I (am) Cyrus, the king, the Achaemenide.

For the sake of comparison I add the epitaph of Cyrus quoted by Strabo, (XV, 3.)

Ω ἄνθρωπε, ἐγὼ Κῦρος εἰμὶ ὁ Καμβύσου, ὁ τὴν αρχὴν Πέρσαις καταστησάμενος καὶ τῆς Ασίας βασιλεύσας. Μὴ οὖν φθονήσῃς μοι τοῦ μνήματος.

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* For the original text of the inscriptions the reader is referred to the translator's Old Persian Grammar, published by Ginn & Co., Boston, Mass. (1892).

THE INSCRIPTION OF DARIUS HYSTASPES AT BEHISTAN.

The longest and most important of the Old Persian inscriptions is the great monument of Behistan. The name *Behistan* forms a dependent compound, the first member being BAGA (*God*) and the second STANA (place.) Behistan or "Place of God" was known to the Greeks who gave it the name *βαγὶσταvον ὂροσ*. This immense rock rises abruptly to a height of 1,700 feet from the plain below. No place in all Persia could Darius have found more fitted for the purpose of holding an everlasting memorial of his reign. The bas-reliefs are uninjured and show a row of nine usurpers bound with a cord about their necks. In front of them stands the monarch who treads upon the prostrate body of a tenth victim. Behind Darius are two attendants, armed with the spear and bow. The figures of the conquerer and his warriors are skillfully executed, while the rebels are intentionally represented as diminutive in size. Above the picture is an effigy of Auramazda, the greatest deity of the Persians.

Over the heads of the king and his captives are placed legends commemorating the monarch's triumphs and showing the ancestry of Darius and the fraud of the usurpers. Below the reliefs in five parallel columns occurs the inscription of nearly one thousand lines, the translation of which I make at this point.

I.

1. I (am) Darius, the great king, the king of kings, the king in Persia, the king of countries, the son of Hystaspes, the grandson of Arshama, the Achaemenide.

2. Says Darius the king my father (is) Hystaspes, the father of Hystaspes (is) Arshama, the father of Arshama (is) Ariyaramna, the father of Ariyararamna (is Caispis*), the father of Caispis (is) Achaemenes.

3. Says Darius the king therefore we are called the Achaemenides: from long ago we have extended† from long ago our family have been kings.

4. Says Darius the king VIII.‡ of my family (there were) who were formerly kings: I am the ninth IX: individually we were (lit. are) kings.

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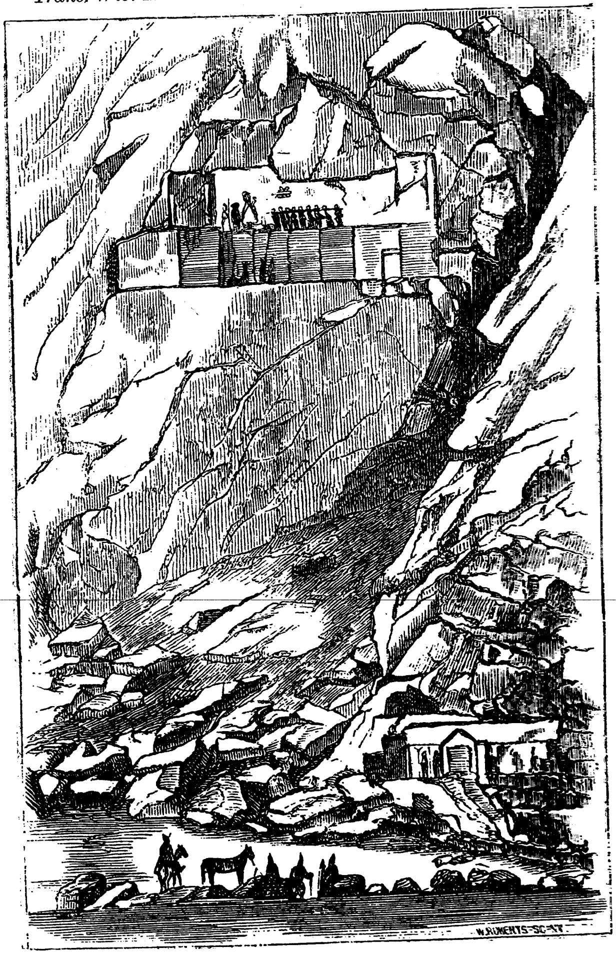
* Caispis is omitted by the carelessness of the stone-cutter. It is easily supplied from the inscription above the head of Darius which repeats these introductory sections; vide infra.

‡ The Persian word AMATA I connect with the Sanskrit root MA *to measure* (Cf. Zend MA and Latin ME-TO). The A is doubtless a prefix corresponding to the Sanskrit A (hither). AMATA would mean *measured hither* or *to the present time*, i. e. reaching to the present. It is possible to emphasize the idea of the root MA (measure): hence the word might signify *measured, tested, tried.*

‡ The numerals are represented by horizontal wedges for the units and oblique for the tens.



The Behistan Mountain.

5. Says Darius the king by the grace of Auramazda I am king: Auramazda gave me the kingdom.

6. Says Darius the king these are the countries which came to me: by the grace of Auramazda I became king of them, Persia, Susiana, Babylon, Assyria, Arabia, Egypt, which are by the sea, Sparda, Ionia, Media, Armenia, Cappadocia, Parthia, Drangiana, Area, Chorasmia, Bactriana, Sogdiana, Gandara, Saka, Thatagus, Haravatis, Maka, in all (there are) XXIII countries.

7. Says Darius the king these (are) the countries which came to me: by the grace of Auramazda they became subject to me: they bore tribute to me: what was commanded to them by me. this was done night and (lit. or) day.

8. Says Darius the king within these countries what man was a friend* him will supported I supported: who was an enemy him well punished I punished; by the grace of Auramazda these countries followed my law: as it was commanded by me to them, so it was done.

9. Says Darius the king Auramazda gave me the kingdom; Auramazda bore me aid until this kingdom was established: by the grace of Auramazda I hold this kingdom.

10. Says Darius the king this (is) what (was) done by me after that I became king; Cambyses by name, the son of Cyrus (was) of our family: he before was king here: of this Cambyses there was a brother Bardiya (i. e. Smerdis) by name possessing a common mother and the same father with Cambyses; afterwards Cambyses slew that Bardiya: when Cambyses slew Bardiya, there was not knowledge† (on the part) of the state that Bardiya was slain: afterwards Cambyses went to Egypt: when Cambyses went to Egypt, after that the state became hostile, after that there was deceit to a great extent in the provinces, both Persia and Media and other provinces.

11. Says Darius the king afterwards there was one man, a Magian, Gaumata by name; he rose up from Paishiyauvada; there (is) a mountain Arakadris by name; from there on the 14th day‡ of the month Viyakhna then it was when he rose up: he then deceived the state; I am Bardiya the son of Cyrus brother of Cambyses: afterwards the whole state became estranged from Cambyses (and) went over to him, both Persia and Media and the other provinces: he siezed the kingdom; on the 9th day of the month Garmapada then it was he thus seized the kingdom; afterward Cambyses died by a self-imposed death.||

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* The Persion word is of doubtful interpretation. It looks like the NOMEN AGENTIS of GAM *to go*, *a goer hither* or a *comer*. The translation *friend* is a conventional one.

† AZDA, a doubtful word. I connect it with the root DA *to know* which occurs in the compound AURAMAZDA.

‡ Lit. with fourteen days; a use of the instrumental which denotes the association of time with an event. This idiom is employed in all like temporal expressions.

|| The word UVAMARSHIYUSH I divide into UVA *self* (Cf. Skt. SVA. Lat. SE) and MARSHIYUSH

12. Says Darius the king this kingdom which Gaumata the Magian took from Cambyses, this kingdom from long ago was (the possesion) of our family: afterwards Gaumata the Magian took from Cambyses both Persia and Media and the other provinces; he acted in accordance with? his own pleasure? he became king.

13. Says Darius the king there was not a man neither a Persian nor Median nor anyone of our family who could make Gaumata the Magian deprived of the kingdom; the state feared him vehemently (or because of his violence); he would smite the state utterly which knew the former Bardiya; for this reason he would smite the state that it might not know me* that I am not Bardiya the son of Cyrus; any one did not dare to say anything against Gaumata the Magian until I came; afterwards I asked Auramazda for help; Auramazda bore me aid; an the 10th day of the month Bagayadis then it was I thus with (my) faithful? men slew that Gaumata the Magian and what men were his foremost allies; there (is) a stronghold Sikayauvatis by name;† there is a province in Media Visaya by name; here I smote him; I took the kingdom from him; by the grace of Auramazda I became king: Auramazada gave me the kingdom.

14. Says Darius the king—the kingdom which was taken away from our family, this I put in (its) place; I established it on (its) foundation; as (it was) formerly so I made it; the sanctuaries? which Gaumata the Magian destroyed I restored. The commerce? of the state and the cattle and the dwelling places and in accordance with ‡ the clans which Gaumata the Magian took from them (I restored); I established the state on (its) foundation both Persia and Media and the other provinces; as (it was) formerly so I brought back what (had been) taken away; by the grace of Auramazda this I did; I labored that our clan I might establish in (its) place; as (it was) formerly, so (I made it); I labored by the grace of Auramazda that Gaumata the Magian might not take away our race.

15. Says Darius the king this (is) what I did, after that I became king.

16. Says Darius the king when I slew Gaumata the Magian afterwards there (was) one man Atrina by name the son of Upadara(n)ma; he rose up in Uvaja (i. e. Susiana); thus he said to the state; I am king in Uvaja; afterwards the people of Uvaja became rebellious (and) went over to that Atrina; he became king in Uvaja; also there (was) one man a Babylonian Naditabira by name the son of Ain.....; he rose up in Babylon; thus he deceived the state; I am Nabukudracara the son of Nabunita; afterwards the whole of the Babylonian state went over to

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die (Cf. Skt. MAR Lat. MORIOR). The meaning also corresponds to the statement in Herodotus III 64-65. that Cambyses died from a wound inflicted by his sword as he was leaping from his horse.

* Note the direct form of expression.

† NAMA is not the accusative of specification but is attacted into the case and even the gender of the subject. Lit. there is a stronghold (its) name (is) Sikayauvatis.

‡ The transition from the accusative to the instrumental is hard to explain.

that Naditabira; Babylon became rebellious; the kingdom in Babylon he seized.

17. Says Darius the king afterwards I sent forth (my army) to Uvaja; this Atrina was led to me bound; I slew him.

18. Says Darius the king afterwards I went to Babylon against that Naditabira who called himself Nabukudracara; the army of Naditabira held the Tigris; there he halted and was on shipboard; afterwards I destroyed the army .... one (army) I made submissive, of the other .... I led; Auramazda bore me aid; by the grace of Auramazda we crossed the Tigris; here the army of Naditabira I slew utterly; on the 27th day of the month Atriyadiya then it was we thus engaged in battle.

19. Says Darius the king afterwards I went to Babylon; when to Babylon ....; there (is) a town Zazana by name along the Euphrates; there this Naditabira who called himself Nabukudracara went with his army against me to engage in battle; afterwards we engaged in battle; Auramazda bore me aid; by the grace of Auramazda the army of Naditabira I slew utterly .... the water bore it away; on the 2nd day of the month Anamaka then it was we thus engaged in battle.

II.

1. Says Darius the king afterwards Naditabira with (his) faithful ? horsemen went to Babylon; afterwards I went to Babylon; by the grace of Auramazda I both seized Babylon and seized that Naditabira; afterwards I slew that Naditabira at Babylon.

2. Says Darius the king while I was in Babylon these (are) the provinces which became estranged from me, Persia, Uvaja, Media, Assyria, Armenia, Parthia, Magus, Thatagus, Saka.

3. Says Darius the king there (was) one man Martiya by name, the son of Cicikhris — there (is) a town in Persia Kuganaka by name — here he halted; he rose up in Uvaja; thus he said to the state; I am Imanis king in Uvaja.

4. Says Darius the king then I was near by Uvaja; afterwards from me .... the people of Uvaja seized that Martiya who was chief of them and slew him.

5. Says Darius the king one man Fravartis by name, a Mede, he rose up in Media; thus he said to the state; I am Khshathrita of the family of Uvakhshatara; afterwards the Median state which was in clans became estranged from me (and) went over to that Fravartis; he became king in Media.

6. Says Darius the king the Persian and Median army, which was by him, it was faithful ? (lit. a faithful (?) thing); afterwards I sent forth an

army; Vidarna* by name, a Persian, my subject him I made chief of them; thus I said to them; go smite that Median army which does not call itself mine; afterwards this Vidarna with the army went away; when he came to Media .... there (is) a town in Media ...... by name — here he engaged in battle with the Medes; he who was the chief among the Medes did not then hold (the army) faithful ?; Auramazda bore me aid; by the grace of Auramazda the army of Vidarna smote that rebellious army utterly; on the 6th day of the month Anamaka then it was the battle (was) thus fought by them; afterwards my army — there (is) a region Ka(m)pada by name — there awaited me until I went to Media..

7. Says Darius the king afterwards Dadarsis by name, an Armenian, my subject, him I sent forth to Armenia; thus I said to him; go, the rebellious army which does not call itself mine smite it; afterwards Dadarsis went away; when he came to Armenia, afterwards the rebellious ones having come together went against Dadarsis to engage in battle .... a village ..... by name in Armenia; here they engaged in battle; Auramazda bore me aid; by the grace of Auramazda my army smote that rebellious army utterly; on the 6th day of the month Thuravahara then it was thus the battle (was) fought by them.

8. Says Darius the king a second time the rebellious ones having come together went against Dadarsis to engage in battle; there (is) a stronghold, Tigra by name, in Armenia — here they engaged in battle: Auramazda bore me aid; by the grace of Auramazda, my army smote that rebellious army utterly; on the 18th day of the month, Thuravahara then it was the battle (was) thus fought by them.

9. Says Darius the king a third time the rebellious ones having come together went against Dadarsis to engage in battle; there (is) a stronghold, U......ama by name, in Armenia — here they engaged in battle; Auramazda bore me aid; by the grace of Auramazda my army smote that rebellious army utterly; on the 9th day of the month, Thaigarcis then it was thus the battle (was) fought by them; afterwards Dadarsis awaited me until I came to Media.

10. Says Darius the king afterwards Vaumisa by name, a Persian, my subject, him I sent forth to Armenia ; thus I said to him; go, the rebellious army which does not call itself mine, smite it; afterwards Vaumisa went away; when he came to Armenia afterwards, the rebellious ones having come together went against Vaumisa to engage in battle; there (is) a region, ... by name, in Assyria — here they engaged in battle; Auramazda bore me aid; by the grace of Auramazda my army smote

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* A nominative in apposition with an accusative. This weak syntax is common to the Old Iranian languages. Artificially the construction can be explained by supplying ASTI *is* and repeating the idea in the form of a pronoun. The boldest case is in III. 2. FRAISHAYAM DADARSHISH *I sent forth Dadarsis*, the nominative being used apparently as an object. For a fuller discussion of the subject the reader is referred to my Old Persian Grammar 61, A, notes, & 2.

that rebellious army utterly; on the 15th day of the month Anamaka, then it was thus the battle (was) fought by them.

11. Says Darius the king a second time the rebellious ones having come together went against Vaumisa to engage in battle; there (is) a region Autiyara by name in Armenia — here they engaged in battle; Auramazda bore me aid; by the grace of Auramazda my army smote that rebellious army utterly; .... of the month Thuravahara .... thus the battle (was) fought by them; afterwards Vaumisa awaited me in Armenia until I came to Media.

12. Says Darius the king afterwards I went from Babylon; I went away to Media; when I went to Media — there (is) a town Kudurus by name in Media — here this Fravartis (i. e., Phaortes) who called himself king in Media went with (his) army against me to engage in battle; afterwards we engaged in battle; Auramazda bore me aid; by the grace of Auramazda I smote the army of Fravartis utterly; on the 26th day of the month Adukanis then it was we engaged in battle.

13. Says Darius the king afterwards this Fravartis with faithful ? horsemen — in that place (was) a region Raga by name in Media — here went; afterwards I sent forth my army against them; Fravatis was seized (and) led to me; I cut off (his) nose and ears and tongue, and to him .... I led; he was held bound at my court; the whole state saw him; afterwards I put (him) on a cross at Ecbatana, and what men were his foremost allies, these I threw within a prison at Ecbatana.

14. Says Darius the king one man, Citra(n)takhma by name, a Sagartian, he became rebellious to me; thus he said to the state; I am king in Sagartia, of the family of Uvakhshatara; afterwards I sent forth the Persian and Median army; Takhmaspada by name, a Mede, my subject, him I made chief of them; thus I said to them; go, the rebellious army, which does not call itself mine, smite it; afterwards Takhmaspada went away with the army (and) engaged in battle with Citra(n)takhma; Auramazda bore me aid; by the grace of Auramazda my army smote that rebellious army utterly and seized Citra(n)takhma (and) brought (him) to me; afterwards I cut off his nose and ears, and to him .... I led; he was held bound at my court; the whole state saw him; afterwards I put him on a cross in Arabia.

15. Says Darius the king this (is) what (was) done by me in Media.

16. Says Darius the king Parthia and Hyrcania .... of Fravartis .... called himself; Hystaspes my father .... army .... afterwards Hystaspes .... allies .... town .... by name .... they engaged in battle .... thus the battle (was) fought by them.

III.

1. Says Darius the king afterwards I sent forth the Persian army to Hystaspes from Raga; when this army came to Hystaspes, afterwards Hystaspes with that army went away — there (is) a town Patigrabana by name in Parthia — here he engaged in battle with the rebellious ones; Auramazada bore me aid; by the grace of Auramazda Hystaspes smote that rebellious army utterly; on the first day of the month Garmapada then it was that thus the battle (was) fought by them.

2. Says Darius the king afterwards it became my province; this (is) what (was) done by me in Parthia.

3. Says Darius the king there (is) a region Margus by name; it became rebellious to me; one man Frada, a Margianian, him they made chief; afterwards I sent forth Dadarsis by name, a Persian, my subject, satrap* in Bactria against him; thus I said to him: go, smite that army which does not call itself mine; afterwards Dadarsis with the army went away (and) engaged in battle with the Margianians; Auramazda bore me aid; by the grace of Auramazda my army smote that rebellious army utterly; on the 23rd day of the month Atriyadiya then it was thus the battle (was) fought by them.

4. Says Darius the king afterwards it became my province; this (is) what (was) done by me in Bactria.

5. Says Darius the king one man Vahyazdata by name — there (is) a town Tarava by name; there (is) a region Yutiya by name in Persia — here halted; he a second time (i. e. after Gaumata) rose up in Persia; thus he said to the state; I am Bardiya the son of Cyrus; afterwards the Persian army which (was) in clans departed from duty; it became estranged from me (and) went over to that Vahyazdata; he became king in Persia.

6. Says Darius the king afterwards I sent forth the Persian and Median army which was by me; Artavardiya by name, a Persian, my subject, him I made chief of them; the other Persian army went with (lit. after) me to Media; afterwards Artavardiya with the army went to Persia; when he came to Persia — there (is) a town Rakha by name in Persia — here this Vahyazdata who called himself Bardiya went with (his) army against Artavardiya to engage in battle; afterwards they engaged in battle; Auramazda bore me aid; by the grace of Auramazda my army smote that army of Vahyazdata utterly; on the 12th day of the month Thuravahara then it was thus the battle (was) fought by them.

7. Says Darius the king afterwards this Vahyazdata with faithul? horsemen then went to Paishiyauvada; from thence he went with an army

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*The Persian word KHSHATRAPAVAN (satrap) is lit. *protecting the kingdom;* KHSHATRA *kingdom* (Cf. ARTAKHSHATRA, Artaxerxes) and PA *protect* (Cf. Skt. and Zend PA, Lat. PA-VI, S. FODA and the root in the Lat. PATER and its cognates.

again against Artavardiya to engage in battle; there (is) a mountain Paraga by name—here they engaged in battle; Auramazda gave me aid; by the grace of Auramazda my army smote that army of Vahyazdata utterly; on the 6th day of the month Garmapada then it was thus the battle (was) fought by them and they seized that Vahyazdata and what men were his foremost allies they seized.

8. Says Darius the king afterwards—there (is) a town in Persia Uvadaidaya by name*—here, that Vahyazdata and what men were his foremost allies, them I put on a cross.

9. Says Darius the king this Vahyazdata who called himself Bardiya he sent forth an army to Harauvatis—there (was) Vivana by name, a Persian, my subject, satrap in Harauvatis—against him (he sent an army) and one man he made chief of them; thus he said to them: go, smite that Vivana and that army which calls itself of Darius the king afterwards this army, which Vahyazdata sent forth, went against Vivana, to engage in battle; there (is) a stronghold Kapishakanis by name—here they engaged in battle; Auramazda bore me aid; by the grace of Auramazda my army smote that rebellious army utterly; on the 13th day of the month Anamaka then it was thus the battle (was) fought by them.

10. Says Darius the king again the rebellious ones having come together went against Vivana to engage in battle; there (is) a region Ga(n)dutava by name—here they engaged in battle; Auramazda bore me aid; by the grace of Auramazda my army smote that rebellious army utterly; on the 8th day of the month Viyakhna then it was thus the battle (was) fought by them.

11. Says Darius the king afterwards this man, who was chief of that army which Vahyazdata sent against Vivana, this chief with faithful ? horseman went away—there (is) a stronghold Arshada by name in Harauvatis—he went beyond thence; afterwards Vivana, with an army on foot went (against) them; here he seized him and what men were his foremost allies he slew.

12. Says Darius the king afterwards the province became mine; this is what was done by me at Harauvatis.

13. Says Darius the king when I was in Persia and Media a second time the Babylonians became estranged from me; one man, Arakha by name, an Armenian son of Han(?)dita,† he rose up in Babylon; there (is)

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* The reader has noticed the constant use of paratax. Instead of bringing the words of the sentence into syntax independent constructions are employed. In no other language is this loose arrangement (which we must feel was original to speech) shown to better advantage than in the old Persian inscriptions.

† The N in Handita as well as the N in Dubana conjecture has supplied. The combination of wedges in the cuneiform text resembles no other characters on the stone and perhaps is the sign for L which otherwise would be wanting in the Old Persian alphabet. I however feel that it is simply a careless writing of the nasal.

a region, Duban(?)a by name—from there he rose up; thus he lied; I am Nabukudracara, the son of Nabunita; afterwards the Babylonian state became estranged from me (and) went over to that Arakha; he seized Babylon; he became king in Babylon.

14. Says Darius the king afterwards I sent forth my army to Babylon; Vi(n)dafra by name, a Mede, my subject, him I made chief; thus I said to them; go, smite that army in Babylon which does not call itself mine; afterwards Vi(n)dafra with an army went to Babylon; Auramazda bore me aid; by the grace of Auramazda, Vi(n)dafra seized Babylon.......... on the 2d day of the month........then it was thus...................
....
....
....

IV.

1. Says Darius the king this (is) what was done by me in Babylon.

2. Says Darius the king this (is) what I did; by the grace of Auramazda it was (done) wholly in (my) way;* after that the kings became rebellious I engaged in XIX battles; by the grace of Auramazda I smote them and I seized IX kings; there was one, Gaumata by name, a Magian; he lied; thus he said; I am Bardiya the son of Cyrus; he made Persia rebellious; there (was) one, Atrina by name, in Uvaja; he lied; thus he said; I am king in Uvaja; he made Uvaja rebellious to me; there (was) one, Naditabira by name, a Babylonian; he lied; thus he said; I am Nabukudracara the son of Nabunita; he made Babylon rebellious; there (was) one, Martiya by name, a Persian; he lied; thus he said; I am Imanis king in Uvaja; he made Uvaja rebellious; there (was) one Fravartis by name, a Mede; he lied; thus he said; I am Khshathrita of the family of Uvakhshatara; he made Media rebellious; there (was) one, Citra(n)takhma by name, in Sagartia; he lied; thus he said; I am king in Sagartia, of the family of Uvakhshatara; he made Sagartia rebellious: there (was) one, Frada by name, a Margianian; he lied; thus he said; I am king in Margus; he made Margus rebellious; there (was) one, Vahyazdata by name, a Persian; he lied; thus he said; I am Bardiya the son of Cyrus; he made Persia rebellious; there (was) one, Arakha by name, an Armenian; he lied; thus he said; I am Nabukudracara the son of Nabunita; he made Babylon rebellious.

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* HAMAHYAYA THARDA is of doubtful interpretation. Rawl. suggested "the performance of the whole"; Oppert "dans toute ma vie; dans toute l'annie, toujours"; Spiegel "in aller Weiser" Many idle attempts have been made to connect THARDA with the Sanskrit ÇARAD, *autumn* used in the Veda metaphorically for *year*, but they are unsatisfactory. I feel that we have nothing which can give us light on this phrase.

3. Says Darius the king these IX kings I seized within these battles.

4. Says Darius the king these (are) the provinces which became rebellious; a lie made them*....that these deceived the state; afterwards Auramazda made them in my hand; as desire (moved) me, thus.........

5. Says Darius the king O thou who wilt be king in the future, protect thyself strongly from deceit; whatever man will be a deceiver, him punish well (lit. him well punished punish, Cf.. I. 8), if thus thou shalt think "may my country be firm."

6. Says Darius the king this (is) what I did; by the grace of Auramazda I did (it) wholly in (my) way;† O though who shalt examine this inscription in the future, let it convince thee (as to) what (was) done by me; do not deceived thyself.

7. Says Darius the king Auramazda (is) a witness? that this (is) true (and) not false (which) I did wholly in my own way.‡

8. Says Darius the king by the grace of Auramazda.................. (what) else (was) done by me to a great extent, that (is) not inscribed on this inscription; for this reason it (is) not inscribed lest whoever will examine this inscription in the future .... it may not convince him (as to) what (was) done by me (and) he may think (it) false.§

9. Says Darius the king who were the former kings, by these nothing (was) done to a great extent as (was) performed ‖ wholly by me though the grace of Auramazda.

10. Says Darius the king............let it convince thee (as to) what (was) done by me; thus.........................for this reason do not hide (this monument); if thou shalt not hide this monument (but) tell (it) to the state, may Auramazda be a friend to thee and may there be to thee a family abundantly and live thou long.

11. Says Darius the king if thou shalt hide this monument (and) not tell (it) to the state, may Auramazda be a smiter to thee and may there not be to thee a family.

12. Says Darius the king this (is) what I did wholly in (my) way;¶ by the grace of Auramazda I did (it); Auramazda bore me aid and the other gods which are.

13. Says Darius the king for this reason Auramazda bore me aid and the other gods which are, because I was not an enemy, I was not a deceiver, I was not a despot... ....family above law, above

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* Perhaps we can supply with Spiegel HAMITRIYA *a lie made them rebellious.*

† Cf. IV. 2.

‡ Cf. IV. 2.

§ Although much has become obliterated yet we have enough to enable us to gain the sense of the passage. The idea is: should I write the memorial of all my achievements, they would be so many that men would lose faith in the testimony of this stone.

‖ Cf. IV. 2. but here THARDA fails to appear.

¶ Cf. IV. 2.

me............................I did.........that whoever for me helped those belonging to my race, him well supported I supported; whenever ....him well punished I punished.

14. Says Darius the king O thou who art king in the future, whatever man shall be a deceiver...............shall be...............(be) not a friend to these; punish these with severe punishment.

15. Says Darius the king O thou who shalt see this inscription in the future which I inscribed or these pictures, thou shalt not destroy (them) as long as thou shalt live; thus guard them.

16. Says Darius the king if thou shalt see this inscription or these pictures (and) shalt not destroy them and shalt guard them for me as long as (thy) family shall be, may Auramazda be a friend to thee and may there be to thee a family abundantly and live thou long and whatever thou shalt do, this for thee (let) Auramazda........ let him grant thy prayers.

17. Says Darius the king if thou shalt see this inscription or these pictures (and) shalt destroy them and shalt not guard them for me as long as (thy) family shall be, may Auramazda be a smiter to thee and may there not be to thee a family and whatever thou shalt do this let Auramazda destroy for thee.

18. Says Darius the king these (are) the men who were there then when I slew Gaumata the Magian who called himself Bardiya; then these men cooperated as my allies; Vi(n)dafrana by name, the son of Vayaspara, a Persian; Utana by name, the son of Thukhra, a Persian; Gaubaruva by name, the son of Marduniya, a Persian; Vidarna by name, the son of Bagabigna, a Persian; Bagabukhsha by name, the son of Daduhya, a Persian; Ardumanis by name, the son of Vahauka, a Persian.

19. Says Darius the king O thou who art king in the future, what .... what Darius ....
....
....
.... I did.

V.

1. Says Darius the king this (is) what I did........................
.... way ....
.... king .... province; this became estranged from me; one man ..imina by name; the (people) of Uvaja made him chief; afterwards I sent forth (my) army to Uvaja; one man Gaubaruva by name, a Persian, my subject, him I made chief of them; afterwards this Gaubaruva with an army went to Uvaja; he engaged in

battle with the rebellious ones; afterwards ....
.... and to him ....
.... he seized and led to
me .... province ....
.... thus it ....
....

2. Says Darius the king ....
....
.... Auramazda .... by the grace of
Auramazda .... I did.

3. Says Darius the king whoever in the future ....
....
....

4. Says Darius the king I
went against Saka ....
.... Tigris .... to the sea ....
.... I seized the enemy .... to ....
.... Saku(n)ka by name, him I seized ....
.... there another as chief ....
.... afterwards ....
....

5. Says Darius the king .... not
Auramazda .... if by the grace of Auramazda
.... I did.

6. Says Darius the king .... worship? Aurmazda: ....
....
....
....

Kossowicz remarks: "Notatu dignum omnium, quantum scio, imperatorum, qui armorum vi atque gloria celebres extiterant, nisi duo, Darium Hystaspi nempe et Napoleonem I—mum, commilitonum nomina, victorias suas recensendo, in publicis monumentis memoriae tradidisse."

THE SMALLER INSCRIPTIONS OF BEHISTAN.

A.

*Over the picture of Darius.**

I (am) Darius, the great king, king of kings, king of Persia, king of the countries, the son of Hystaspes, the grandson of Arshama, the Achaemenide. Says Darius the king my father (is) Hystaspes, the father of Hystaspes (is) Arshama, the father of Arshama (is) Ariyaramna, the father of Ariyaramna (is) Caispis, the father of Caispis (is) Achaemenes. Says Darius the king therefore we are called Achaemenides; from long ago we have extended; from long ago our family have been kings. Says Darius the king VIII of my family (there were) who were formerly kings; I am the ninth IX; individually we are kings.

B.

Under the prostrate form.

This Gaumata the Magian lied; thus he said; I am Bardiya, the son of Cyrus; I am king.

C.

Over the first standing figure.

This Atrina lied; thus he said; I am king in Uvaja.

D.

Over the second standing figure.

This Naditabira lied; thus he said; I am Nabuk (u) dracara, the son of Nabunita; I am king in Babylon.

E.

Upon the garment of the third standing figure.

This Fravartis lied; thus he said; I am Khshathrita of the family of Uvakhshatara; I am king in Media.

F.

Over the fourth standing figure.

This Martiya lied; thus he said; I am Imanis, king in Uvaja.

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* Cf. I, I-4.

G.

Over the fifth standing figure.

This Citra(n)takhma lied; thus he said; I am king in Sagartia, of the family of Uvakhshatara.

H.

Over the sixth standing figure.

This Vahyazdata lied; thus he said; I am Bardiya, the son of Cyrus; I am king.

I.

Over the seventh standing figure.

This Arakha lied; thus he said; I am Nabuk (u) dracara, the son of Nabunita; I am king in Babylon.

J.

Over the eighth standing figure.

This Frada lied; thus he said; I am king in Margus.

K.

*Over the ninth standing figure.**

This (is) Saku(n)ka, the Sakian.

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* Herodotus mentions the high cap which was peculiar to the garb of the Sakians. It is interesting to note that the figure is represent on the stone wearing this national head-dress. Cf. plate, opp. page 242.

THE INSCRIPTION OF ALVEND.

This inscription is engraven upon two niches on a large block of stone near the base of Mt. Alvend. Not only is the monumental fame of Darius perpetuated by the Behistan mountain, but in different parts of the Persian empire this monarch caused to be inscribed historic records of his reign. At Persepolis the palaces declare the name of their founder and his prayers for the protection of heaven. To Darius beyond all others we are indebted for what we have of the Paleography of Persia. After translating the inscription indicated above I shall take up the remaining ones of this king at Persepolis, Suez, etc.

A great god (is) Auramazda who created this earth, who created yonder heaven,* who created man, who created the spirit? of man, who made Darius king, one king of many, one lord of many. I (am) Darius the great king, king of kings, king of the countries possessing many kinds of people, king of this great earth far and wide, the son of Hystaspes, the Achaemenide.

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* ASMAN (*heaven*) is literally *a stone* as we know from its cognate in Sanskrit. Probably the Persians regarded the sky as a solid dome; cf. the Hebrew word RAQI (A) (Gen. I. 8), and our *firmament* (firmamentum).

THE INSCRIPTIONS OF SUEZ.

A crowned head is carved upon the stone together with the legend:

A.

Darius the great king, king of kings, king of the countries, the son of Hystaspes, the Achaemenide.

Above are a dozen lines of Persian cuneiform text the translation of which follows.

B.

A great god (is) Auramazda, who created yonder heaven, who created this earth, who created man, who created the spirit ? of man, who made Darius king, who gave the kingdom to Darius; what great .... I (am) Darius the great king, king of kings, king of the countries possessing many people, king of this great earth far and wide, son of Hystaspes, the Achaemenide. Says Darius the king I am a Persian; with (the help of) Persia I seized Egypt; I commanded to dig this canal * from the Nile by name a river which flows in Egypt to the sea, which goes from Persia; afterwards this canal was dug there as I commanded ....

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* Cf. Herodotus IV. 39. *λήγει δὲ αὕτη (ἡ ʽΑραβίη), ὀυ λήγουσα εἰ μη νόμῳ, ἐς τον κολπον τὸν ʼΑραβιον, ἐς τον Δαρεῖος ἐκ τοῦ Νέιλου διώρυχα ἐσήγαγε.*

THE INSCRIPTION OF LONDON.

The following short inscription can be seen in the British Museum on a cylinder which furnishes a fine specimen of gem engraving. A warrior in his charriot is represented as attacking at full speed a lion,* the symbol of power. This warrier from his crown we can interpret as King Darius. He holds his bow ready for action, while the charioteer urges on the steeds. This cylinder was carried to England from Egypt.

I (am) Darius the king.

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* On the Persian sculptures, the lion and bull occur often, as emblems of strength. Metaphors of this kind are frequent in all oriental literature. In making a list of the epithets of the god Indra in the Veda, I was struck with the repeated comparisons of this sort. However, the Vedic poets drew from the stall as the most fertile source of metaphors, and it was the later Sanskrit which used the beasts of the forest more extensively for that purpose. (e. g, the tiger of men, etc.) In Biblical literature the reader is referred to Ezekiel i. 10. "As for the likeness of their faces, they four had the faces of a man, and the face of a lion on the right side." Daniel vii. 4. "The first was like a lion and had eagles wings." The familiar national emblems of later date, the Roman eagle, the British lion, etc., all had their origin in this early conception.

THE INSCRIPTIONS OF DARIUS AT PERSEPOLIS.

The inscriptions of Persepolis show that same spirit of patriotism which characterizes the record on Mt. Behistan. The superiority of Persia over the provinces of the empire is set forth by the monarch with the purpose of elevating the feelings of his countrymen and of keeping alive ever in their hearts the love of country. The palace of Darius shows the ruins of several apartments with external chambers which were evidently guard-rooms. The roof of a large room, fifty feet square, was supported by pillars, the bases of which remain to-day. This edifice is one of those ruins which represent the combined work of several successive Achaemenian kings. All the structures stand upon the same platform around which are great walls of hewn stone. Two inscriptions are found above the wall and one on two pillars, which read as follows:

A.

Above the wall surrounding the palace.

The great Auramazda, who (is) the greatest of the gods, he made Darius king; he gave to him the kingdom; by the grace of Auramazda Darius (is) king. Says Darius the king this (is) the country Persia which Auramazda gave me, which, beautiful, possessing good horses, possessing good men, by the grace of Auramazda and (by the achievements) of me Darius the king, does not fear an enemy. Says Darius the king let Auramazda bear me aid with (his) fellow gods and let Auramazda protect this country from an army, from misfortune, from deceit; may not an enemy.... come unto this country, nor an army, nor misfortune nor deceit; this I pray of Auramazda....with (his) fellow gods; this let Auramazda give me with (his) fellow gods.

B.

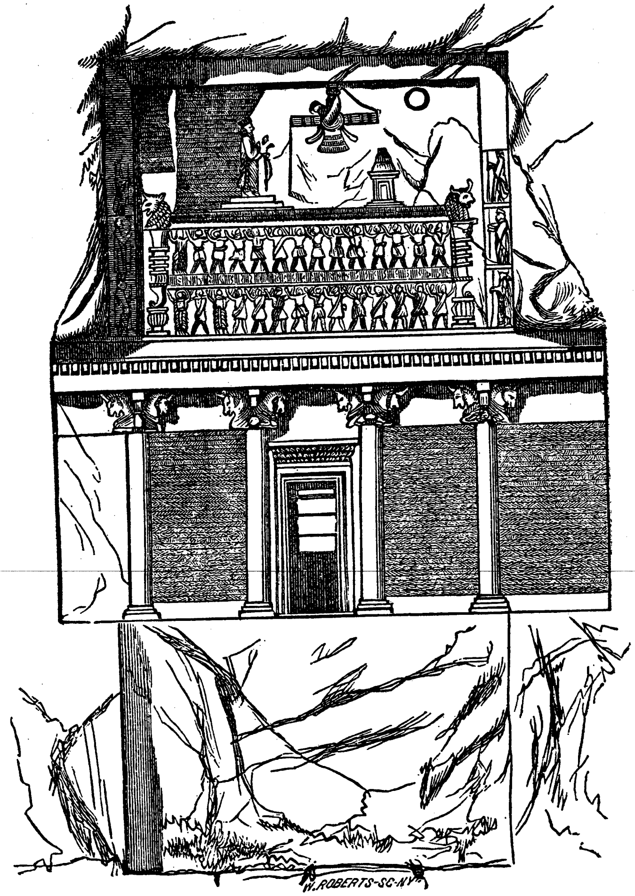
Another inscription above the wall.

I (am) Darius the great king, king of kings, king of many countries, the son of Hystaspes, the Achaemenide. Says Darius the king by the grace of Auramazda these (are) the provinces which I subdued with (the help of) that Persian army, (and) which feared me (and) brought to me tribute; Uvaja, Media, Babylon, Arabia, Assyria, Egypt, Armenia, Cappadocia, Sparda, Ionia, which (are) of the dry (land) (and) which (are) of the sea, and the provinces which (are) in the east, Sagartia, Parthia, Zara(n)ka, Haraiva, Bactria, Sugda, Uvarazamiya, Thatagus, Harauvatis, India, Ga(n)dara, Saka, Maka. Says Darius the king if thus thou shalt think "may I not fear an enemy," protect this Persian state; if the Persian state shall be protected, may this goddess (namely) this spirit (of patriotism) for a long time unharmed, descend upon this race.

C.

Over the pillars in the palace.

Darius the great king, king of kings, king of the countries, the son of Hystaspes, the Achaemenide, who built this palace.



The Tomb of Darius.

THE INSCRIPTION ON THE TOMB OF DARIUS.

Naqshi—Rustam is the burial place of Darius.

On the face of a mountain which rises to the perpendicular height of 900 feet are cut the excavations which are doubtless tombs. These relics have a common external appearance. They are carved into the rock fourteen feet deep in the form of a cross the upright section of which is about ninty feet, the tranverse division about fifty feet. Four pilasters about seven feet apart ornament the tranverse section, in the midst of which is the door of the tomb. On the division above the facade of this sepulchre are the sculptures. A double row of fourteen figures support two cornices. Two bulls form the pillars at each end of the upper cornice. On an elevated pedestal of three steps stands a figure dressed in a flowing robe holding his bow in his left hand. Without doubt this is the effigy of him who lies buried beneath. Opposite the standing form on a pedestal of three steps is an altar upon which the sacred fire is burning, while above is a disk probably representing the sun of which the fire blazing at the shrine is the symbol. Above is the image of Auramazda. One of these structures Ker-Porter visited and with great difficulty explored its interior. Although he was not able to read the inscription, yet he conjectured that this was the tomb of Darius. I quote him at this point. "The second tomb is the only one whereon the marks of an inscription can be traced; but over the whole tablet of the upper compartment, letters are visible wherever they could be introduced; above the figures, between them and the altar, along the side, from top to bottom, in short, everywhere, we see it covered with the arrow-headed characters and in good preservation. What a treasure of information doubtless is there to the happy man who can decipher it. It was tantalizing to a painful degree, to look at such a sealed book, in the very spot of mystery, where probably, its contents would explain all. But it certainly is a very distinguishing peculiarity of this tomb that it alone should contain any inscription, and that the writing on it is so abundant; a circumstance that might warrant the supposition of this being the tomb that was cut by the express orders of Darius Hystaspes to receive his remains." (Travels in Georgia, Persia, Armenia, ancient Babylonia etc. etc. by Sir Robert Ker-Porter, vol. I, p. 523).

Before translating the inscription I wish to call the attention of the reader to Herod III. 88. *πρῶτον μέν νυν τύπον ποιησάμενος λίθινον (Δαρεῖος) ἕστησε. ζῷον δέ οἱ ἐνῆν ἀνὴρ ἱππεὺς. ἐπέγραψε δὲ γράμματα λέγοντα τάδε. Δαρεῖος ὁ Ὑστάσπεος σύν τε τοῦ ἵππου τῇ ἀρετῇ καὶ Οἰβάρεος τοῦ ἱπποκόμου ἐκτήσατο τὴν Περσέων βασιληίην.*

A.

A great god is Auramazda, who created this earth, who created yonder heaven, who created man, who created the spirit? of man, who made Darius king, one king of many, one lord of many. I (am) Darius the great king king of kings, king of the countries possessing many kinds of people, king of this great earth far and wide, son of Hystaspes the Achaemenide, a Persian, the son of a Persian, an Aryan, an Aryan offspring. Says Darius the king by the grace of Auramazda these (are) the provinces which I seized afar from Persia; I ruled them; they brought tribute to me.................what was commanded to them by me, this they did; the law which (is) mine, that was established; Media, Uvaja, Parthia, Haraiva, Bactria, Suguda, Uvarazamis, Zara(n)ka, Harauvatis, Thatagus, Ga(n)dara, India, Sakae Humavarkae, Sakae Tigrakhaudae, Babylon, Assyria, Arabia, Egypt, Armenia, Cappadocia, Sparda, Ionia, Sakae beyond the sea, the Ionians wearing long hair,[*] Patians, Kusians, Macians, Karkians. Says Darius the king Auramazda, when he saw this earth ....afterwards gave it to me: he made me king; I am king; by the grace of Auramazda I established it on (its) foundation; what I commanded to them, this they did as desire came to (lit. was) me. If perchance thou shall think that manifold (lit. a manifold thing) are these provinces which Darius the king held, look at the picture (of those) who are bearing my throne,[†] in order that thou mayst know them; then to thee will be the knowledge (that) the spear of a Persian man hath gone forth afar; then to thee will be the knowledge (that) a Persian man waged battle far from Persia. Says Darius the king this (is) what (was) done; all this by the grace of Auramazda I did; Auramazda bore me aid until this (was) done; let Auramazda protect me from .... and my race and this country; this I pray of Auramazda; this let Auramazda give me: O man, what (are) the commands of Auramazda, may he (make them) revealed to thee; do not err; do not leave the right path; do not sin.

B.

A great god (is) Auramazda who .... made spirit? of man.....................................above Darius the king ....Says Darius the king by the

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[*] Cf. the Homeric καρηκομωοντες.

[†] The northern throne of the great palace contains five tiers of ten warriors supporting the platform on which the king is represented sitting, surrounded by his attendants.

grace of Auramazda..

....

....

.... is violence ....

....

.... violence ....

C.

Gaubaruva, a Patisuvarian, spear-bearer of Darius the king.

D.

Aspacana, quiver-bearer?, a server of the arrows of Darius the king.

E.

This (is) a Macian.

THE INSCRIPTIONS OF XERXES AT PERSEPOLIS.

A.

Upon each one of the four pillars of the entrances to the palace of Xerxes

A great god (is) Auramazda who created this earth, who created yonder heaven, who created man, who created the spirit? of man, who created Xerxes king, one king of many, one lord of many. I (am) Xerxes the great king, king of kings, king of the countries, possessing many kinds of people, king of this great earth far and wide, the son of Darius the king, the Achaemenide. Says Xerxes the great king by the grace of Auramazda, this entrance possessing all countries I made; much else (that is) beautiful (was) done by this Persian (people) which I did and which my father did; whatever (that has been) done seems beautiful, all that we did by the grace of Auramazda. Says Xerxes the king let Auramazda protect me and my kingdom and what (was) done by me and what (was) done by my father, (all) this let Auramazda protect.

B.

Upon the pillars on the western side of the palace, where Xerxes is represented standing with two attendants.

Xerxes the great king, king of kings, the son of Darius the king, the Achaemenide.

C.

Upon the wall by the stairs of the palace.

A great god (is) Auramazda who created this earth, who created yonder heaven, who created man, who created the spirit ? of man, who made Xerxes king, one king of many, one lord of many. I (am) Xerxes the great king, king of kings, king of the provinces possessing many kinds of people, king of this great earth far and wide, son of Darius the king, the Achaemenide. Says Xerxes the great king by the grace of Auramazda this palace (lit. seat) I made; let Auramazda protect me with the gods and my kingdom and what (was) done by me.

D.

The above inscription is repeated on the western stairs of the palace.

E.

Upon the highest pillar near the southern stairs.

A great god (is) Aurmazda who created this earth, who created yonder heaven, who created man, who created the spirit ? of man, who made Xerxes king, one king of many, one lord of many. I (am) Xerxes the great king, king of kings, king of the provinces possessing many kinds of people, king of this great earth far and wide, son of Darius the king, the Achaemenide. Says Xerxes the great king by the grace of Aura* Mazda this palace (lit. seat) Darius the king made who (was) my father; let Auramazda protect me with the gods and what (was) done by my father Darius the king, (all) this let Auramazda protect with the gods.

F.

The above inscription is repeated upon the walls of the southern stairs.

G.

Upon the stairs of the palace.

A great god (is) Auramazda who created this earth, who created yonder heaven, who created man, who created the spirit? of man, who made Xerxes king, one king of many, one lord of many. I (am) Xerxes the great king, king of kings, king of the provinces possessing many kinds of people, king of this great earth far and wide, the son of Darius the king, the Achaemenide. Says Xerxes the great king what (was) done by me here and what (was) done by me afar, all this I did by the grace of Auramazda; let Auramazda protect me with the gods and my kingdom and what (was) done by me.

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*Notice that the two members of the compound are separated. In the Zend Avesta we read AHURA MAZDA, AURA signifies *lord* (Cf. Sanskrit ASURA, Zend AHURA); MAZDA we can divide into MAZ *great* (Cf. Sanskrit MAHAT, Lat. MAG-NUS, Gothic MAG, Eng. MIGHT.) and DA *to know*.

THE INSCRIPTION OF XERXES AT ALVEND.

The following inscription is engraven upon two niches cut into a small rock:

A great god (is) Auramazda, who (is) greatest of the gods, who created this earth, who created yonder heaven, who created man, who created the spirit? of man, who made Xerxes king, one king of many, one lord of many. I (am) Xerxes the great king, king of kings, king of the provinces possessing many kinds of people, king of this great earth far and wide, the son of Darius the king, the Achaemenide.

THE INSCRIPTION UPON THE VASE OF COUNT CAYLUS.

This vase contains the three customary forms of cuneiform writing and a line of Egyptian hieroglyphics. This relic is preserved in Paris. Four fragments of similar alabaster vases containing the same quadrilingual inscription have been found by W. K. Loftus in Susa, and are to be seen to-day in the British Museum.

I (am) Xerxes, the great king.

THE INSCRIPTION AT VAN.

This inscription is about sixty feet from the plain below, engraven upon a niche in an enormous rock which rises to the perpendicular heighth of one hundred feet:

A great god (is) Auramazda who (is) the greatest of the gods, who created this earth, who created yonder heaven, who created man, who created the spirit ? of man, who made Xerxes king, one king of many, one lord of many. I (am) Xerxes the great king, king of kings, king of the provinces possessing many kinds of people, king of this great earth far and wide, the son of Darius the king, the Achaemenide. Says Xerxes the king Darius the king who (was) my father he by the grace of Auramazda did what (was) beautiful to a great extent and he commanded to carve this place ——? he did not make the inscription inscribed; afterwards I commanded to inscribe this inscription; let Auramazda protect me with the gods and my kingdom and what (has been) done by me.

THE INSCRIPTION OF ARTAXERXES I.

This inscription, which is quadrilingual is engraven upon a vase which is preserved in the treasury of St. Mark's at Venice.

Artaxerxes,* the great king.

THE INSCRIPTION OF DARIUS II.

Above the posts of the windows in the palace at Persepolis.

(This) lofty stone structure (has been) made by (one belonging to) the race of Darius the king.

THE PECULIARITIES OF INSCRIPTIONS OF ARTAXERXES MNEMON AND ARTA XERXES OCHUS.

These inscriptions show that the work of decay had already begun in the grammatical structure of the language. Such careless irregularities occur in them that I wish to call the attention of the reader to a few before I begin the translation: (1) what should be a genitive becomes attracted into the nominative on account of proximity; (2) the nominative is attracted into the case of a preceding noun for the same reason, yet allowing the predicate to be in the proper case; (3) the nominative is thrust into the accusative as if it were to become a direct object, yet the passive construction is retained. In consequence of these irregularities it will be impossible to make a literal translation as I have done heretofore, but I shall translate as if the regular constructions were employed.

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* The cuneiform text spells the name of the monarch on the vase ARDAKHCASHCA. This spelling must be due either to foreign pronunciation or to the ignorance of the workman, Elsewhere the cuneiform characters give the regular ARTAKHSHATRA.

THE INSCRIPTION OF ARTAXERXES MNEMON AT SUSA.

This inscription is upon the base of one of the columns in the ruins of what once must have been a great palace. Much of this building was used for the pavement of other edifices by the races which in after time possessed this spot.

A.

I (am) Artaxerxes, the great king, king of kings, the son of Darius* the king.

B.

Upon the base of a pillar in a large row of columns. This palace seems to have been fashioned after the model of that of Darius at Persepolis. In connection with this edifice it is interesting to refer to Dan. viii. 2. "and it came to pass when I saw, that I was in Susa (or Shushan) in the palace" etc.

Says Artaxerxes the great king, king of kings, king of the countries, king of the earth, the son of Darius the king; Darius (was) the son of Artaxerxes the king; Artaxerxes (was) the son of Xerxes the king; Xerxes (was) the son of Darius the king; Darius (was) the son of Hystaspes, the Achaemenide; this building Darius, my ancestor made..... ....Artaxerxes (my) grandfather........Anakata and Mithra........by the grace of Auramazda the building I made; let Auramazda, Anahata and Mithra protect me............

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* Darayavus (Darius) although having a stem in u is treated like nouns whose stems end in a. So in Prakrit there is a strong tendency for the so-called first declension to trespass upon the others, thus breaking down the barriers which were observed by the Sanskrit.

THE INSCRIPTION OF ARTAXERXES OCHUS AT PERSEPOLIS.

Upon the steps of the palace.

A great god (is) Auramazda who created this earth, who created yonder heaven, who created man, who created the spirit? of man, who made me, Artaxerxes, king, one king of many, one lord of many. Says Artaxerxes the great king, king of kings, king of countries, king of the earth. I (am) the son of Artaxerxes, the king; Artaxerxes (was) the son of Darius the king; Darius (was) the son of Artaxerxes the king; Artaxerxes (was) the son of Xerxes the king; Xerxes (was) the son of Darius the king; Darius was the son of Hystaspes by name; Hystaspes was the son of Arshama by name, the Achaemenide. Says Artaxerxes the king this lofty stone structure (was) made by me during my reign (lit. under me). Says Artaxerxes the king let Auramazda and the god Mithra protect me and this country and what (was) done by me.

THE OLD PERSIAN LANGUAGE.

We have now translated all the inscriptions of the Achaemenides which have been discovered. Before closing this work I wish to speak a word for the Old Persian language. Not only the historian feels an interest in reading the records written by the monarchs of one of the greatest empires of past ages, but the philologist recognizes in the speech, which has been preserved to us through the ambition of these oriental despots another offspring of our mother-tongue. Of that great sisterhood of languages, to which our own speech belongs, the Old Persian is a most ancient member. In its grammatical structure it most closely resembles the Vedic dialect of the Sanskrit and we have to rely almost entirely upon the combined help of the Sanskrit and Zend for an understanding of its vocabulary. For the sake of illustration I add a few Old Persian words with their cognates in the other members of our family.

Old Persian.	Sanskrit.	Zend.	Greek.	Latin.	Gothic.	English.
AITA.	ETAT.	AETAD.	*τό.*	ISTE.	THA.	THE.
UPARIY.	UPARI.	UPARA.	*ὑπέρ.*	super.	UFAR.	OVER.
TUVM.	TVAM.	THWAM.	*σύ (τύ).*	TU.		THOU.
GAM.	GAM.	GAM.		VENIO.	QUAM.	COME.
PITAR.	PITAR.	PITA.	*πατήρ.*	PATER.	FADAR.	FATHER.

In its phonetic system the Old Persian showed a striking analogy to that of the Greek in allowing an original sibilant to pass over into the aspiration. e. g. AH *be* for Skt. AS.; so in Greek *ὁ* and *ἡ* for Skt. SAS and SA.

A few peculiar points of syntax I shall note.* The nominative is sometimes used apparently as the direct object of a verb. The instrumental assumes a temporal sense by denoting the association of time with an event. The dative has disappeared from the language and its place is taken by the genitive. This datival genitive is simply a pregnant use of the possessive genitive and occurs likewise in the Prakrit and late Sanskrit. e. g. KHSHATRAM MANA FRABARA, he gave the kingdom to me (made

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* For a fuller discussion of the peculiarities of Old Persian syntax, cp. my article in the Proceedings of the Oriental Society (1892) p. 100.

it mine by giving). The relative pronoun is frequently equivalent in meaning and usage to the Greek article agreeing with its antecedent not only in gender and number but also in case. When used in this way its independent character is lost.

The imperfect and aorist sometimes appear without augment as often in the Veda. With the loss of this augment they sacrifice their peculiar character. After MA prohibitive the sense is that of an optative or imperative. The infinitive often expresses purpose as the dative infinitive in the Ṛig Veda.

The participle of KAR *do* regularly takes a genitive for the instrumental, perhaps on account of the nominal character of the participle.

THE EFFECTS OF CHANGES IN TEMPERATURE ON THE DISTRIBUTION OF MAGNETISM.

By HIRAM B. LOOMIS, Ph. D.,

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The following paper is an account of some experiments undertaken to determine more accurately, if possible, the kind of change which takes place when a magnet is heated and cooled. An extensive investigation of the changes in magnetic distribution, moment, and permeability is under way and considerable work has been done in all three lines. Though the results so far obtained as to changes in moment and permeability are not deemed complete enough for publication, the investigation as to the changes in distribution may be of interest.

The subject will be considered under the following heads:

I. Historical Sketch.
II. Description of Apparatus and Experiment.
III. Calculation and Verification of Results.
IV. Discussion of Results.

I. HISTORY.

*About 1825, Kupffer magnetized a steel bar and placed it in a water bath. Near it he suspended a magnetic needle and determined the period of 300 swings before the temperature of the bar had changed. The bath was then heated to 100° C., and the period of 300 swings again determined. The bar was alternately heated and cooled between the same limits of temperature, and determinations of the period were made. His results may be summed up as follows: If a permanent magnet be heated above the temperature of magnetization, its magnetic moment decreases. On again cooling the moment increases, but not enough to make up the first loss. This is true of the first three or four heatings and coolings.

†Riess and Moser also experimented on the change in magnetic moment by swinging magnets in the earth's field and determining the period of

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* Wiedemann's Electricität III., p. 753.

† Riess und Moser, Pogg. Ann. 17, p. 425, 1829.

vibration. For needles 34 lines long they found the following formula held:

$$I' = I\,[1 - 0.000324\,(t' - t)\,d],$$

where I and I′ are the intensities of magnetization at the temperatures t and t′ on the Reamur scale, and d is the diameter of the magnets. For needles 2 inches long the numerical factor is 0.000432, showing that the proportional change in intensity of magnetization is greater in shorter magnets. Their temperature limits were 0° and 80° R. By swinging their magnets at different temperatures they found the change in moment proportional to the difference in temperature as is shown by their formula, which is to be applied with caution for their magnets had not been brought to what we call the permanent state.

In 1851,* Lamont found that when a permanent magnet was alternately heated and cooled fifteen or sixteen times between fixed limits of temperature, it reached a permanent state in which it had a definite magnetic moment for a given temperature and always returned to that moment when brought to the corresponding temperature, provided only it had never passed beyond the temperature limits mentioned above. The higher the temperature, the smaller was the magnetic moment.

†Prof. G. Wiedemann has made some careful investigations on the influence exerted by the temper of the steel and the original intensity of magnetization. He used bars 22 cm. long and 1.35 cm. in diameter. Before being magnetized, they were alternately placed in melting snow and boiling water fifteen times, in order to bring the steel itself as far as possible into such a state that alterations in temperature would produce no structural change. The bars were magnetized in a coil at a temperature of 0°. They were then carefully placed in a box of sheet copper before the needle of a magnetometer and the deflection was observed by a telescope and scale. The temperatures of 0° and 100° C. were obtained by means of melting snow and boiling water. His results for magnets that have reached the permanent state show that in the case of hard steel magnets the change in moment is nearly proportional to the moment at 0°, while for tempered and soft steel magnets, the ratio of the change to the moment at 0° C. increases with the moment. As his results give a good idea of the size of the changes under discussion, I append the following table from his paper:

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* Lamont, Pogg. Am. 82, p. 440, 1851.

† G. Wiedemann, Pogg. Am. 100, p. 235, 1852; 103, p. 563, 1858; 122, p. 355, 1664.

M_0	M_{100}	M'_0	N_0	N_{100}	$\frac{M_0-M_{100}}{M_0}$	$\frac{M_0-M'_0}{M_0}$	$\frac{M_0-N_0}{M_0}$	$\frac{N_0-N_{100}}{N_0}$
I. *Hard steel bar.*								
71.5	41.5	44.8	37.	33.2	0.420	0.373	0.483	0.103
134.5	89.2	96.	85.5	77.8	0.321	0.286	0.364	0.090
195.	134.3	146.2	133.3	120.	0.311	0.250	0.316	0.100
II. *Tempered steel bar.*								
44.	27.	30.	29.	27.	0.386	0.318	0.341	0.0690
148.5	107.2	114.5	110.3	101.	0.278	0.229	0.257	0.0814
219.5	165.	179.	172.	156.	0.249	0.184	0.216	0.0930
317.	239.	260.7	251.2	226.	0.246	0.178	0.207	0.1003
Soft steel bar, No. 1.								
85.	45.	......	38.	33.2	0.471	....	0.553	0.126
141.	73.5	......	68.5	57.	0.479	....	0.514	0.168
193.	99.	......	101.	78.5	0.487	....	0.478	0.223
209.5	109.5	......	115.	88.2	0.477	....	0.451	0.233
Soft steel bar, No. 2.								
95.5	49.7	54.2	45.	39.	0.479	0.432	0.529	0.133
136.5	73.	81.5	69.	59.	0.465	0.403	0.495	0.145
174.8	92.5	108.3	93.4	76.	0.471	0.378	0.466	0.186
Very soft steel bar which had been heated and slowly cooled many times.								
51.5	34.5	37.	......	......	0.330	0.282	....	....
80.5	54.5	58.	......	......	0.323	0.279	....	....
113.	76.	82.	......	......	0.328	0.274	....	....
159.5	103.3	116.5	......	......	0.353	0.270	....	....
181.	113.5	131.	......	......	0.373	0.277	....	....

M_0 is the intensity of magnetization before any change in temperature has taken place; M_{100}, when first heated to 100° C.; M'_0, after being again cooled to 0° C. N_0 and N_{100} are the intensities of magnetization at the temperatures indicated by the subscripts after the magnet has been heated and cooled fifteen times.

With reference to the theory of these changes Prof. Wiedemann says: "Besides the permanent effect due to an alteration in temperature there is a temporary change. Each heating diminishes the permanent moment of the molecules. Moreover, for the time being, it loosens the particles of the body and lessens the strain in which they have been placed by the action of external forces, therefore they return a little toward their first position of equilibrium, in which they were held by the forces acting between them before the external forces came into play. Heating thus diminishes the magnetization temporarily, but on cooling the molecules return to their former position and the lost magnetization is regained.

"We can produce entirely analogous phenomena if we change the temperature of bodies which have suffered a change of form (tortion) as a result of the mechanical forces, and observe the increase and decrease of this on heating and cooling."

*Barus and Strouhal carefully distinguished the mechanical effect of heating from the purely magnetic effect. They found that a temperature 20° or 30° C. above that of the water in which a glass hard steel rod was dipped in hardening produced quite perceptible annealing effects. This change in the hardness of steel would naturally affect the magnetization.

According to their exprriments, if a glass hard steel rod is thoroughly annealed by being kept at the temperature of boiling water for a day or two and then magnetized to saturation at the temperature of the room, the loss in magnetism on being heated to the boiling point is relatively small and is nearly independent of the time it is kept there. Nearly the whole change takes place during the first ten minutes. On the other hand, if the bar is not first annealed, the change is much larger and is not complete after twenty-two hours heating.

We pass now to investigations on changes in distribution due to temperature changes. This field has not been extensively worked. These two investigations are all that could be found.

†Kupffer determined at two different temperatures the period of vibration of a short needle placed opposite different parts of a long magnet, and found the proportional change in distribution greater at the ends than in the middle of the bar. All his measurements were made before the bar had reached the permanent state.

‡Poloni measured the distribution at various temperatures, by slipping a coil from different parts of the magnet to such a distance that the magnet exerted practically no effect, and measuring the quantity of electricity thus induced. He worked between temperatures 0° and

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*Bull U. S. Geol. Sur. No. 14, p. 151.

†Kuppfer, Pogg. Ann. 12, p. 133.

‡Poloni, Beibl. 5, p. 802. Atti della R. Acad. dei Lincei 5, p. 262, 1881.

200° C., using an oil bath to obtain his high temperatures. The changes were quite regular between 0° and 180° C., but were very large near 190° C. Between 0° and 180° C., he found that the following formula held:

$$M = A \left[1 + K^{-l} - K^{-x} - K^{(l + x)} \right]$$

where M is the induction in the magnet at a distance x from one of the ends; l, the length of the magnet; A, a quantity depending only on the temperature, while K is sensibly constant for a given magnet.

II. DESCRIPTION OF APPARUTUS AND EXPERIMENT.

The determination of the reason for and laws governing the increase and decrease in magnetism from changes in temperature forms an interesting problem, and the investigation was undertaken in the hope of throwing new light on the subject. The apparatus employed was suggested by Prof. Rowland, under whose direction the investigation was conducted, and will be best understood from the diagram on plate XI.

A and B are two cylindrical soft steel magnets (Stub's steel of the same temper as when purchased) 30.1 cm. long, and 0.55 cm. in diameter. They were magnetized to saturation in a coil, the magnetic circuit being completed by an iron casting, which happened to be of suitable size and shape. They were then brought to the permanent state by alternate heating and cooling. In both ends of each holes were bored and threads cut. The depth of these holes in magnet A was 8 mm. at each end. In magnet B the hole at the south end was 11 mm. deep, that at the north end 7 mm. In the experiment the magnets were placed perpendicular to the earth's field.

Pieces of brass rod H H H H of the same diameter as the magnets were screwed into their ends and acted as guides for the two coils (to be described presently), so that after they had been slipped off the magnets, they could be slipped back again without trouble. DD is a brass rod about 1.5 metres long, holding the two magnets together in the position shown in the figure. CC are pieces of non-conducting material to keep the magnets from changing temperature by conduction along the rod DD.

E and F are two coils of very fine wire wound on paper tubes which just fit the magnets. They consisted of 150 turns (five layers of thirty turns each), and were about 7 mm. wide. Their frames were joined by a brass rod PP, of such length that when the coil E was at the center of the magnet B, the coil F was also at the center of the magnet A. By means of this rod they could be moved simultaneously over corresponding portions of the two magnets. At G is a gauge which regulates the distance the coils are moved at a time, so that as they are moved step by step from one end of the bar to the other, the steps will be of equal length. By loosening a screw the coils may be moved from the middle of the magnet to either end at one step.

The cross sections of two cylindrical double boxes made of sheet zinc are indicated at S and T. At K K are openings in which corks holding thermometers were inserted. At L L are openings into the space between the two parts of the double box. Through these a current of steam or cold water was passed to keep the space containing the magnets at the requisite temperature. The temperatures employed were 14° and 99.5° C. The water used to produce the lower temperature was city water direct from the faucet. A fairly constant temperature was easily maintained. M N, M N, are openings by which the magnets were introduced and through which the bars D D and PP passed. They were about 2.5 cm. in diameter and 20. cm. long, und were stuffed with cotton, the better to maintain the temperature of the interior.

The exploring coils, an ordinary astatic galvanometer of low resistance, an earth inductor, and a resistance box were connected up in series. At first the exploring coils were so joined that the currents produced by moving them opposed each other. Beginning at the middle of the magnets the coils were moved step by step to one end, the throw of the needle being observed for each step. The coils were moved so far in the last measurment that practically no lines of induction passed through them as was determined by experiment. Similar observations were made for the other half of the magnets. This gives the excess of the number of lines of induction passing from a certain section of one magnet into the air over that passing out of a corresponding section of the other magnet, that is the difference of distribution of magnetism in the two magnets. These measurments are taken first (say) when A and B are both at 14°C, and and again when A is at 14°C, but B at 99.°5 C. The difference between the two sets after they have been reduced to the same scale by the earth inductor readings is evidently the change in distribution in B due to the change in the temperature. By this method the quantity observed is of about the same magnitude as the quantity we desire to obtain.

To get the distribution of magnetism of the bars, the difference in distribution was first measured as above at the lower temperature, then the connections of the coils were changed so that the induced currents were in the same direction and the sum of the distributions was measured in a similar way. In this case extra resistance had to be added from the resistance box to keep the readings on the scale.

III. CALCULATING OF RESULTS.

The formula for the ballistic galvanometer is

$$Q = k \sin\frac{\vartheta}{2}$$

where Q is the quantity of electricity; k, a constant factor; and ϑ the angular throw of the needle. The observations were made with telescope and scale. Calling d the observed throw and r the distance of the mirror from the scale.

$$\tan 2\vartheta = \frac{d}{r}$$

Expanding $\sin\frac{\vartheta}{2}$ we have

$$\text{Sin}\,\frac{\vartheta}{2} = \frac{d}{2r}\left[\,1 - 0.344\left(\frac{d}{r}\right)^2 + \,\right];$$

this formula was used in reducing the large readings.

The earth inductor readings were taken frequently and were substantially the same throughout the experiment. The throw of the needle due to the earth inductor when both magnets were at 14° C. was 39.5 scale divisions; when one magnet was at 99.°5 C. and the other at 14° C., it was 37.8. The average throw due to slipping the exploring coils over a certain portion of the magnets when one was hot and the other cold, was multiplies by $\frac{39.5}{37.8} = 1.045$ to reduce to the scale of readings taken when both magnets were cold. Corresponding readings were then subtracted, giving the change in distribution in terms of the scale divisions. The reduction to absolute measure was as follows: The effective area of the earth inductor as determined by previous observers is 20,716 sq. cm. The value of the horizontal component of the earth's field at and near the position in which the earth inductor was placed has been determined by numerous observers, and by various methods, and may safely be taken as within 1 per cent. of 0. 2 C. G, S units. The total number of lines of induction cut by turning the earth inductor was 2 H A = 8,286.4. As the throw was 39.5 scale divisions, each division correspouded to $8{,}286.4 \div (39.5 \times 150) = 1.398$ C. G. S. lines of induction. The factor 150 is due to the 150 turns of the exploring coils. The change in distribution in scale divisions obtained above was then multiplied by 1.398 giving the change in linear distribution in C. G. S. lines of induction per 2.17 cm., that being the distance the coils were moved at each step.

In determining the difference in distribution, the angles observed were quite small. The largest was less than 2°, making the angular throw of the needle less than 1°. The deflections in scale divisions were therefore taken as proportional to $\sin \frac{\vartheta}{2}$. The error in the case of the largest reading would not exceed one part in 3,500. The error in the result is still less, as it is obtained by subtracting two throws.

SPECIMEN CALCULATION.

Magnet A.

Middle to North End.

Steps.	Average observed throw at 14° C.	Average observed throw at 99.°5 C.	Corrected throw at 99.°5 C.	Difference in distribution in scale divisions.	Difference in distribution in C. G. S. lines of inductions.
I..........	18.0	17.5	18.3	— 0.3	— 0.4
II..........	18.4	18.1	18.9	— 0.5	— 0.7
III........	11.8	12.6	13.2	— 1.4	— 2.0
IV	— 7.2	— 4.2	— 4.4	— 2.8	— 3.9
V..........	—34.3	—27.2	—28.4	— 5.9	— 8.3
VI	—42.0	—27.7	—28.9	—13.1	—18.3
VII	—49.0	—19.4	—20.3	—28.7	—40.2
End	— 5.4	— 2.2	— 2.3	— 3.1	— 4.3

In finding the sum of the distributions it was found necessary to make use of the formula given on p. 279, because the angles were too large to take $\sin \frac{\vartheta}{2}$ proportional to $\tan 2\vartheta$. The corrected readings were reduced to absolute measure in the way just described. We have now the sum and difference of the linear distribution of the two magnets. One-half the sum plus one-half the difference gives the distribution of one, one-half the sum minus one-half the difference gives that of the other. The distributions at the higher temperature were obtained by subtracting the change in distribution due to the heating.

The induction at each point of the magnet was obtained by adding up the number of lines of induction passing out of the magnet beyond the point in question.

Tables of the results for magnets A and B are given on pages 282–83. The first column gives the distance of the exploring coils from the centers of the magnets at the end of each step. The second and fourth columns gives the number of C. G. S. lines of induction passing out from the magnet at 14° and 99.°5 C. respectively in the step of the coil shown in the first column. The third column gives the change in distribution. The fifth and sixth columns gives the magnetization at the two temperatures, i. e. the number of C. G. S. lines of induction per square centimeter passing through the magnet at the point indicated. The seventh column gives the proportional change in magnetization at different points of the magnet.

In the fifth and sixth columns two values are given for the center of the magnet, calculated from the two ends, and serve to indicate the degree of accuracy attained. The variation is considerably less than one per cent. The second and third columns from which all the others are calculated give the means of at least five or six separate determinations, which agree well among themselves. The results were further checked by slipping the coils from the middle of the magnet clear off each end at both temperatures. The variation between this measurement and the others was always less than one-half of one per cent. This was considered quite good as it is impossible to slip the coils over this whole distance at the same rate at which they were slipped over the small divisions.

In plate XI our results are shown graphically. The full lines give the distribution at 14° C and 99.°5 C. The dotted lines give the change in distribution due to this change in temperature. The scale of ordinates, in the last curves is ten times that of the distribution curves.

In addition to the checks upon accuracy already mentioned, the following entirely independent determinations of the magnetic moments of the two magnets were made. In the tables of distribution pp. 282–83, we are given the number n of lines of induction issuing from little divisions of the bar, as well as the distance d of these divisions from the center of the magnet. A first approximation to the moment is given by the formula:

$$M = \frac{1}{4\pi} \Sigma \text{ nd}.$$

Magnet A.

Distance from center of magnet.	Distribution at 14° C.	Change in distribution.	Distribution at 99°.5.	I_{14} Induction at 14° C.	$I_{99.5}$ Induction at 99°.5.	$\frac{I_{14}-I_{99.5}}{I_{14}}$
	70.1	— 4.3	65.8			
15.20				296.	278.	.060
	428.5	—40.2	388.3			
13.03				2106.	1918.	.089
	285.4	—18.3	267.1			
10.86				3309.	3044.	.080
	204.9	— 8.3	196.6			
8.68				4175.	3875.	.071
	146.8	— 3.9	142.9			
6.51				4795.	4479.	.065
	91.2	— 2.0	89.2			
4.34				5180.	4586.	.062
	56.6	— 0.7	55.9			
2.17				5419.	5092.	.060
	18.6	— 0.4	18.2			
0				{5498. 5453.	{5169} 5126	.060
	— 17.9	0.	— 17.9			
2.17				5377.	5050.	.060
	— 55.5	+ 0.4	— 55.1			
4.34				5143.	4818.	.063
	— 96.9	+ 2.5	— 94.4			
6.51				4734.	4420.	.066
	—142.1	+ 3.2	—138.9			
8.68				4134.	3834.	.072
	—199.9	+ 6.2	—193.7			
10.86				3289.	3015.	.083
	—276.3	+14.8	—261.5			
13.03				2122.	1910.	.100
	—432.6	+39.2	—393.4			
15.20				294.	247.	.159
	— 69.7	+11.2	— 58.5			

Magnet B.

Distance from center of magnet.	Distribution at 14°	Change in distribution.	Distribution at 99.°5.	I_{14} Induction at 14°.	$I_{99.5}$. Induction at 99.°5.	$\frac{I_{14}-I_{99.5}}{I_{14}}$.
	61.0	— 3.9	+ 57.1			
15.20				258.	242.	.062
	359.5	— 39.6	+ 319.9			
13.03				1777.	1594.	.103
	227.6	— 15.1	+ 212.5			
10.86				2738.	2491.	.090
	159.7	— 6.0	+ 153.7			
8.68				3413.	3141.	.079
	139.4	— 3.4	+ 136.0			
6.51				4002.	3716.	.071
	108.1	— 2.1	+ 106.0			
4.34				4458.	4163.	.066
	81.4	— 1.5	+ 80.0			
2.17				4802.	4501.	.062
	43.5	— 0.1	+ 43.4			
				{ 4986. { 4950.	{ 4685. { 4650.	.060
	3.6	+ 0.7	+ 4.3			
2.17				4965.	4668.	.060
	— 36.2	+ 1.1	— 35.1			
4.34				4812.	4520.	.060
	— 79.8	+ 2.0	— 77.8			
6.51				4475.	4191.	.063
	— 128.3	+ 2.4	— 125.9			
8.68				3933.	3659.	.069
	— 188.6	+ 6.6	— 182.0			
10.86				3136.	2890.	.078
	— 266.3	+ 19.0	— 247.3			
13.03				2011.	1845.	.082
	— 406.4	+ 35.4	— 371.0			
15.20				294.	277.	.057
	— 69.7	+ 4.1	— 65.6			

To this value the following correction was added: If A B, in Fig. 1, is the length of one of these divisions of the magnet, and C D a part of the distribution curve supposed to be straight, then the area A B D C represents the number of lines of induction issuing from the magnet in the length A B. Let F be the center of gravity of the triangle C E D. It is evident that the portion of the distribution represented by the triangle should be multiplied by the abscissa of F, not of H, therefore a correction

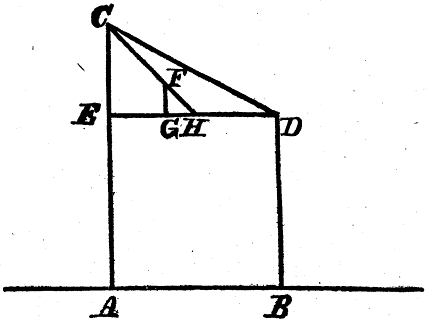


Fig. 1.

$$\Sigma \text{ area of } C\,E\,D \times G\,H$$

was added to the summation already given. From this calculation the following results were obtained:

	Magnets.	A.	B.
M_{14}	Moment at 14° C	2298	2060
$M_{99.5}$	Moment at 99.°5 C	2140	2018
$M_{14} - M_{99.5}$	Loss	158	142
$\frac{M_{14} - M_{99.5}}{M_{14}}$	Proportional loss	0.0687	0.0689
	Intensity at 14° C	322	289
	Intensity at 99.°5 C	300	283

The magnetic moments were also determined by swinging the magnets at the two temperatures in a known field. The experiments were performed with great care and gave the following results:

	Magnets.	A.	B.
M_{14}	Moment at 14° C	2359	2091
$M_{99.5}$	Moment at 99.°5 C	2197	1947
$M_{14}-M_{99.5}$	Loss	166	146
$\frac{M_{14}-M_{99.5}}{M_{14}}$	Proportional loss	0.0686	0.0687
	Intensity at 14° C	339	298
	Intensity at 99.°5 C	316	277

The difference between these two sets of values is considerable, in the case of magnet A the variation amounts to two per cent. This may be due to the fact that only an approximation could be made to the moments of inertia of the magnets because of the holes in the ends, where a slight error would affect the result materially, the distance from the center being 15 cm. The moments of inertia were calculated by dividing the magnet into two parts, an inner core and an outer shell extending beyond the core at both ends. On the other hand it is to be noticed that the ratios $\frac{M_{14}-M_{99.5}}{M_{14}}$ differ by less than one part in 300. In this ratio the moment of inertia of the magnet is eliminated. I think on the whole that the accuracy of the work is fairly well shown.

IV. DISCUSSION OF RESULTS.

The result of the experiment may be stated as follows: If a magnet be heated after it has been brought into the permanent state, the proportional loss in distribution is greatest at the ends and least in the middle. A glance at the table on pages 282–83, or at the curves on plate XI, will show this. The same fact may be stated in other words as follows: The proportional change in the number of lines of induction passing through a cross-section of the magnet is greater, the nearer the section is to the end, as is shown by column seven in the table on page 282–83. This is different from the result obtained by Poloni, who found the proportional change sensibly constant throughout the magnet. It could not be expected that the small difference noticed here could be detected by his method which consisted in measuring two large quantities and subtracting them in order to obtain a small difference. In the method employed in this research the quantities measured differed but little in size from the quantities desired, and much greater accuracy is easily obtained.

I would suggest the following explanation: Prof. Ewing has recently made an important addition to Weber's theory of magnetism. He says the forces which hold the little molecular magnets in position are largely the mutual attractions and repulsions of these molecular magnets themselves. In applying Ewing's theory to the case in hand, let us consider a row of magnetic molecules A B C, etc.

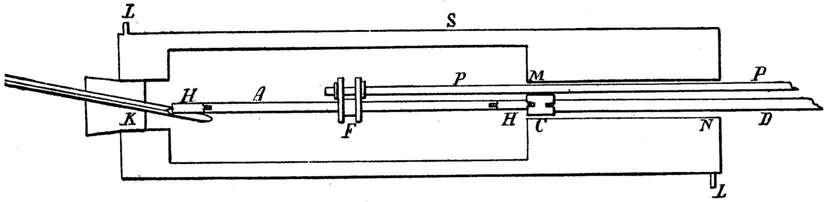
A B C H I J K L
— — — — — — — — — — — — —

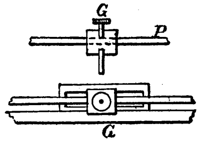
J is held in position by the action of H I, etc., on the one side and K L. etc., on the other, while A has only B C, etc., to act upon it. It is evident that the force holding J in position is greater than that acting on A. Suppose the bar of which this line of molecules is a part is heated. If in this process the energy of vibration of A and J receive equal increments, it is evident that the increase of amplitude of A will be greater than that of B. Now the magnetic moment contributed by each molecule is the moment of the molecule resolved along the direction of magnetization of the bar. The moment contributed by A would suffer a larger proportional loss than that contributed by J, and so the loss would be greatest at the ends.

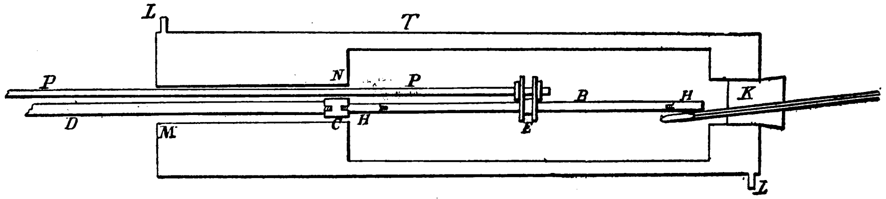
There are other facts pointing in this direction, e. g., when a magnet is heated before it has reached the permanent state, Kupffer found, as already stated, that the proportional permanent loss was greatest at the ends. In some rough tests I have made on this point, heating the bar almost to redness, I have found the proportional loss at the ends nearly twice as great as at the center of the bar. This would naturally follow from the supposition made, for the force holding the end molecules in position being less, they are more easily set in such violent vibration as to swing out of one position of equilibrium into another.

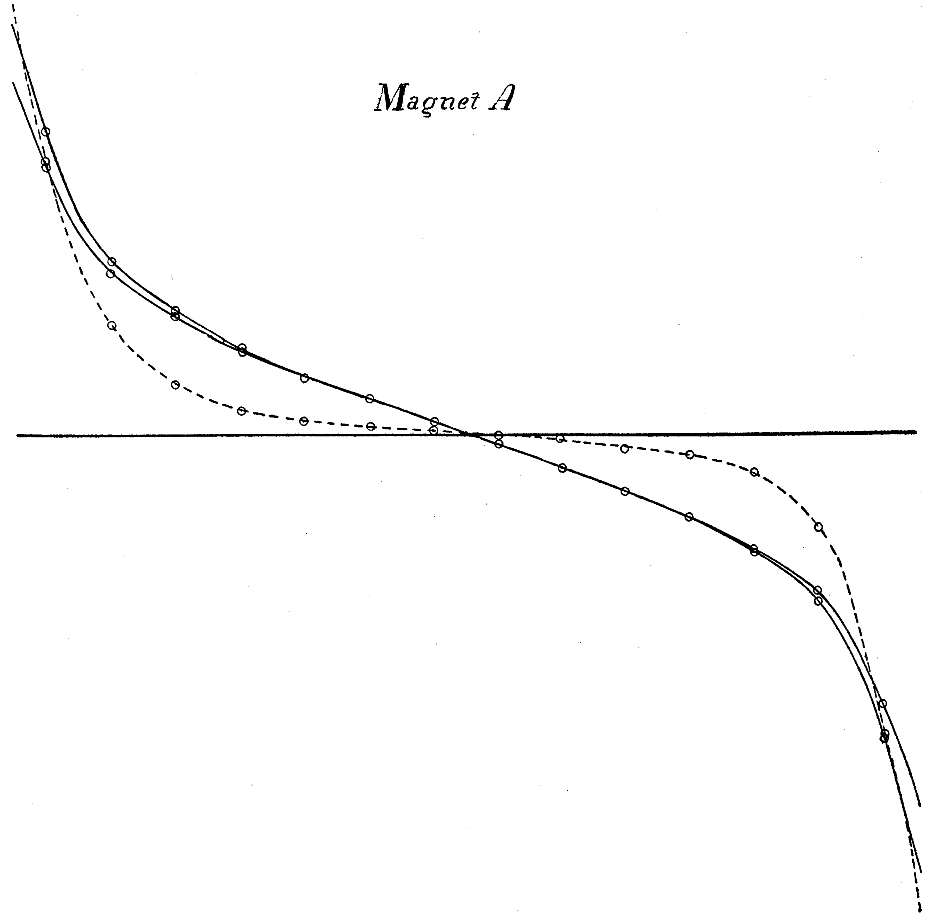
I am tempted to add a single remark on another part of the investigation. In every case tried so far, the area of the cycle of magnetization (the largest magnetizing force being the same for all temperatures) is always smaller for the higher temperature. I have only experimented on soft steel. If the same thing is true for iron and is as marked in degree, I should expect alternate current transformers to work more efficiently at high than at low temperatures. I understand that some efficiency tests point in this direction.

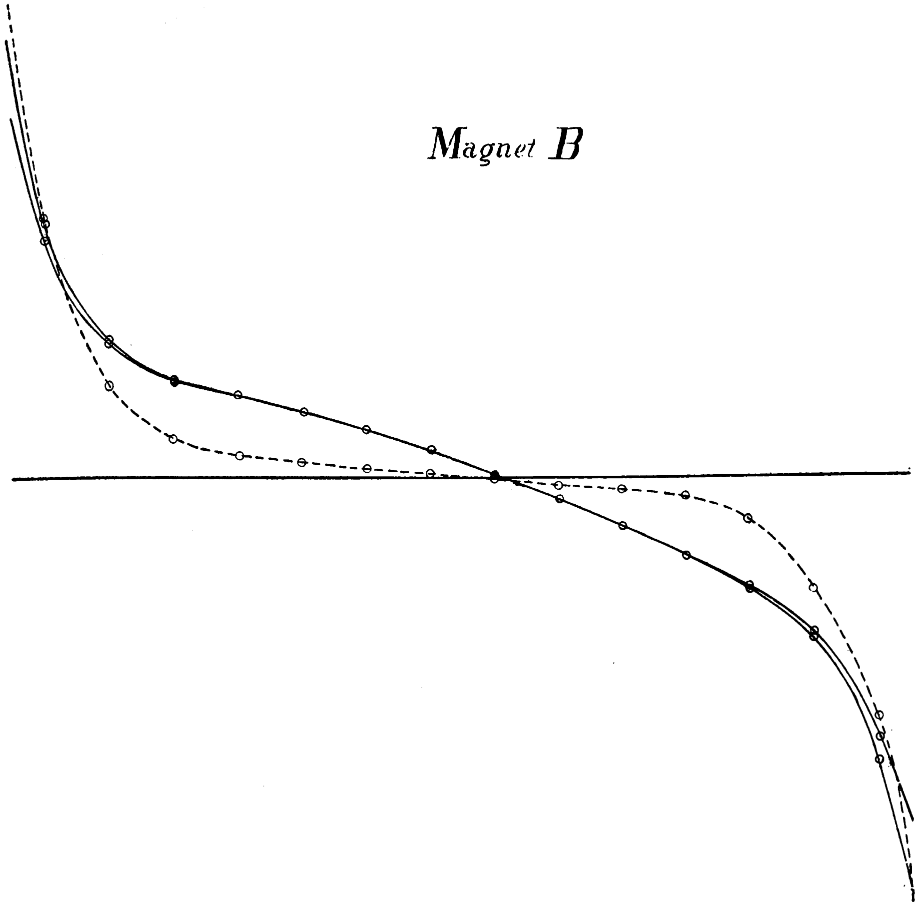
MADISON, WIS., December 28th, 1891.








Magnet A


Magnet B

EARLY LUTHERAN IMMIGRATION TO WISCONSIN.*

By KATE A. EVEREST.

The first immigration of Germans to Wisconsin in large numbers was that of the so-called Old Lutherans of Pomerania and Brandenburg, who came between 1839 and 1845, as a result of the attempt by King Frederick William IV., of Prussia, to unite the Lutheran and Reformed faiths.

My purpose is to sketch the history of that movement with the emigration that followed and the forming of several German settlements in this state.

Philip Schaff divides the history of the Lutheran church into five periods. The first reaches from the Reformation to 1580, the date of the adoption of the Book of Concord; the second from 1580 to 1700, when the doctrinal system was defined in opposition to Romanism, Calvinism and the milder forms of Lutheranism; the third period reaches from 1700 to the middle of the eighteenth century, and is the time when Pietism was exercising its moderating influence; fourth, the period of Rationalism, which reached the higher circles, the clergy, and the universities, and created a revolution in theology; fifth, the period of the revival of evangelical theology and religion at the third centennial of the celebration of the Reformation in 1817.†

From Reformation times there had been attempts to reconcile the followers of Luther with those of Melancthon and Zwingli, but the year 1580 marks their failure. In that year the Book of Concord was adopted which strictly defined the Lutheran faith in distinction from both Calvinism and the milder forms of Lutherism represented by Melancthon.‡

The controversy had been carried on hotly by the followers of each reformer. At his death, Melancthon said, "For two reasons I desire to to leave this life: first, that I may enjoy the sight which I long for of the son of God and of the church in Heaven; next, that I may be free from the monstrous and implacable hatred of the theologians." ‖

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* For information in regard to the Wisconsin communities, I am indebted to the pastors of the churches: Rev. Gram, Rev. E. Pankou, Rev. R. Grabau, Rev. A. W. Keibel, of Wisconsin, and Rev. Philip von Rohr, of Minnesota, also to Dr. Falge, Mr. Blumenfeld and others who have generously given me the information at their disposal.— K. A. EVEREST.

† Schaff-Herzog Encyclopedia of Religious Knowledge, article. "Lutheranism."

‡ Brockhaus Conversations--Lexicon. Vol. XI, article 'Union.'

‖ Gardiner's "Thirty Years War." p. 13.

The basis of the Lutheran doctrine was the "unaltered[*] Augsburg confession," the Smalcald article, and Luther's catechisms.

By the Peace of Augsburg (1555), the only Protestant faith recognized in Germany was the Lutheran and that the unaltered Augsburg confession, but in the Peace of Westphalia (1648), both Lutheranism and Calvinism were given a legal standing.

At the beginning of the Thirty Years War it is estimated that between seventy and ninety per cent. of the population of Germany were Protestant and by far the larger part of that number were Lutherans. The seat of Lutheranism was northern Germany, while in the south the German princes had adopted Calvinism. The Reformed faith or Calvinism had taken root in Germany partly from Switzerland, the home of Zwingli, and partly through the teachings of Melancthon, but it never gained that hardy growth in Germany, says Gardiner, that it had in its native soil. It was the religion of the courts, and according to the principle of the times, it became the religion of the people, (*cujus regio*, *ejus religio.*)

From 1580 to the close of the seventeenth century the lines between the two Protestant faiths were drawn still more closely, and the first modification of dogmatic principles was effected by the influence of Spener and the Pietists. Doctrine became subordinate to "inner light" and to practical piety. It was like the Methodist revival in England but did not result in secession.[†]

Meanwhile the thought of union was being revived. Frederick I. of Prussia called councils of Lutherans and Reformed theologians at Berlin for the sake of obliterating differences, and in 1737, Frederick William I. sought to unify church usages by abolishing certain forms. But the times were doing more. Rationalism was at work modifying creeds, so that at the end of the eighteenth and beginning of the nineteenth century the Lutheran church had but few representatives.[‡] The old hatred seemed strange, even incomprehensible to the new race. Rationalism was above dogmatic strife and Pietism regarded the eternal love as the essence of Christianity. Hence the idea naturally arose that Protestantism might well return to its early unity.[‖] Of this idea Schleiermacher was the spokesman and Frederick William III. its propagator, though they differed materially as to the manner in which it was to be carried out.

The beginning of this century was rich with new national life for Germany. Romanticism and the War of Liberation gave rise to a revival of the past. It was a time of peculiar activity and awakening, which called out German patriotism and above all new political aspirations.

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[*] The Augsburg confession was edited and altered by Melancthon; hence two forms: the *invariata editio* and *variata editio*.

[†] Brockhaus, XVI, p. 37.

[‡] Brockhaus, XI, p. 269.

[‖] Treitschke, Staaten-Geschichte der Neuesten Zeit. II, p. 239.

By all the leaders in this movement a constitution with popular representation was demanded. The idea that the people should participate in government and legislation underlay every attempt at reform. Even in religious matters the same right was recognized. Thus as early as 1813 great importance was attached to the necessity of a free church constitution. The great representative of this idea was Schleiermacher. For this he wrote and worked unceasingly, believing that in this way only could the union be brought about,* but the spirit of absolutism at the Prussian court which was unfavorable to political constitutions, was not less so to a free church constitution.

The year 1817 marks the beginning of a new epoch in religious matters. In that year Claus Harnes published his ninety-five theses against rationalistic apostasy and in the same year at the three hundredth anniversary of the Reformation, King Frederick William III., of Prussia, proclaimed the union of the Reformed and Lutheran churches. The great point of difference between the two creeds lay in the doctrine of the Lord's Supper; the Lutherans taught the real presence of Christ's body "in," "with," and "under" the bread and wine of the sacrament; the Calvinists made these symbolic of the real spiritual presence to believers only. Other points of difference related to the doctrine of predestination which Luther had not taught in any strict sense; but the Reformed church laid great emphasis on moral character, and for that reason was more inclined to the idea of unity than the Lutherans who emphasized doctrinal points.

To the king who was of the Reformed faith the union seemed most simple. "According to my opinion," he had said, "the communion strife is only an unfruitful theological subtlety, of no account in comparison with the fundamental faith of the Scriptures."† The fact that he was outside of the church to which the great majority of his people belonged, was a source of great regret to him. Possessed of a deeply religious nature and for some time under pietistic influences, the union had been one of his dearest objects. Though the act may have been praiseworthy, and was performed by the king in the profound belief that he was called to do that work, yet his unfortunate belief in the sacred prerogative of kings which led him to carry out the reform in a thoroughly absolute manner, was destined to call forth an opposition which ended in the partial failure of the attempt. The union was proclaimed without the consent of the churches, and in 1822, a new agende was drawn up by Bishop Eylert and the court theologians, and in 1830, was rigidly enforced. Schleiermacher, the upholder and defender of the Union, was strongly opposed to the agende, partly on account of its source, namely the royal

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*Weber's Weltgeschichte, vol. XIV, p. 900. Brockhaus, articles "Union" and "Schleiermacher."

†Treitschke II, p. 240.

will instead of the free choice of the church, partly on account of its contents, on the ground that they were antiquated and reactionary.

"The Union rested not simply upon a weakening of the opposing Evangelical doctrines," says Weber. "but upon positive dogmatic principles."* It was ostensibly a liberal union leaving the interpretation of disputed points to the conscience of the individual while the Bible only was recognized as the ground of faith and life.

While the movement had many warm supporters and was imitated by other German courts, namely, by Baden, Nassau and Rheinpfälz, yet it was not heartily supported by the rationalistic element, and on the other hand, aroused a new Lutheran consciousness. It was taken as an attempt to root out Lutheranism which the revival of Germany's great past was more likely to restore. This was especially the case in those parts of Prussia where Lutheranism existed almost unmixed, where, then, there was no sympathy with Reformed doctrines and the union was not felt as a practical necessity. This was the case in North Germany — Saxony, Mecklenburg and in Pomerania. "It seemed," says Treitschke, "like an uprising of Reason against Revelation."†

For some years the opposition was confined to literary polemics,‡ but in 1830 when the new agende was enforced by cabinet orders, Prof. Scheibel of Breslau founded a separate society of two or three hundred families, and being refused permission to worship according to the old agende, Scheibel left the country. Many Silesian pastors followed his example and resistance spread rapidly to Erfurt, Magdeburg and different parts of Pomerania. At Erfurt the leader of the movement and afterwards of the emigration to America was Rev. Johannes A. A. Grabau, pastor of the Evangelical church. In spite of an early education under the influences of a pastor of the United faith, Grabau seems to have kept his preference for the Lutheran church. Finally, in 1836, he reached the conclusion that the Union was contrary to the Scriptures and declared publicly that he could no longer use the new agende with good conscience. Being questioned by the counsellor of the Consistory, he replied that the new form in the administration of the Lord's Supper did not express the belief of the Lutheran church, and that their faith was curtailed and weakened in the new spirit of the times. His society agreed with him and when he was suspended from his office and a new pastor was put in charge, they followed him to his house where services were held. This, too, was forbidden, but they decided "to obey God rather than men." The separate society grew until it reached a membership of nearly 400. Meanwhile, at Magdeburg, another small body of Lutherans had separated from the Union church and were holding services at the home of a captain of the guards, Henry von Rohr. The movement was

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* Weber 14, p. 900.

† Treitschke, Vol. II, p. 243.

‡ Schaff-Herzog II, 1376.

spreading in Pomerania and many pastors and laymen were being persecuted. In 1837, Grabau was imprisoned and, at that time, there were said to be twenty pastors in prison or banished.* Laymen who refused to send their children to the United schools, or who availed themselves of the administration of Luthern pastors in baptism or marriage ceremonies, but especially those who refused to pay the taxes required for the support of a pastor of the United faith were imprisoned, fined or otherwise punished.

At length Capt. von Rohr who had been deprived of his position as captain of the guards, for his refusal to conform, assisted Grabau to escape from prison where, it was claimed, he was illegally detained. They reached Seehof, on the cost of Pomerania in safety. Previous to this time, frequent calls had come to Grabau from the Pomeranian churches which had been deprived of their pastors, and he now visited and conducted services in the different societies. Already the question of emigration had been talked of here and letters were received from friends in Ohio. Grabau advised them to wait until it was definitely settled whether the Lutheran faith would be tolerated. Accordingly, letters were sent to the government asking, in case it should not be tolerated, for permission to emigrate. To the first question, the answer was ;" The Lutheran church is within the United church and outside of it, the King will tolerate no Lutheran church in this land."† Permission was given to emigrate, in case they proved to the satisfaction of the government that they had a pastor, but not otherwise. In consequence of this, many societies in Pomerania and the one at Magdeburg placed themselves in communication with Grabau, asking him to become their pastor. Grabau, meanwhile, had been imprisoned a second time, but he received permisssion to emigrate on strict conditions, namely, that he go directly to Hamburg where they were to embark, accompanied by police officers, lest he hold services on the way.

This was in the spring of 1839 and with Magdeburg as a center, a large emigration was arranged for that year. Capt. von Rohr was chosen to engage passage for them and to go in advance to America and choose places for settlement. He chose Buffalo N. Y., and Milwaukee. Just why he selected Wisconsin, it is impossible to say, but after travelling through New York, Ohio, Illinois and Wisconsin, in order to find the best possible location for a settlement, Wisconsin and New York seemed the most favorable. It is thought that the climate which resembles that of North Germany was one inducement. Another was the prospect of obtaining finely wooded lands, always highly prized by the Germans, at low prices. Capt. von Rohr was very fond of the hunt and the west doubtless attracted him strongly.‡ The position of Wisconsin too, as to the routes of

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* Lebenslauf des Ehrwurdigen J. A. A. Grabau von John A. Grabau (son). p. 26.

† Life of Grabau. p. 35.

‡ Letter from Rev. Philip von Rohr (his son). Winona, Minn.

travel through the Great Lakes must have been another favorable consideration. Land was plenty and cheap in Wisconsin, and land offices had been established within a few years in Milwaukee, Mineral Point and Green Bay.

To defray the expenses of the journey, a common treasury was formed to which the wealthier members contributed part of their means to assist the poor to accompany them. Directors were appointed for each company, to take charge of the money and distribute it according to the needs of the poorer people.

Passage was engaged for one thousand people in five American sail vessels. Rev. E. F. L. Krause, a pastor from Silesia with his society accompanied them. They emigrated in the latter part of July and reached Buffalo, October 5th. Capt. von Rohr had met them in New York and told them of the places he had chosen and their advantages. Accordingly about one half settled in and near Buffalo while the remainder came to Wisconsin with Capt. von Rohr.

These were chiefly Pomeranians. It is doubtless this body of immigrants that is mentioned in Mr. Buck's Pioneer History of Milwaukee. "The year 1839," he says, "brought the first installment of immigrants from Germany and Norway. The effect of their arrival with their gold and silver wherewith to purchase land was electric . . . . Whereas Milwaukee had been under financial depression before, now all doubts about the future were dissipated." Again he says: "The first German colony arrived in 1839. It consisted of about eight hundred men, women and children [the number is probably exaggerated]. They brought with them the necessary housekeeping utensils and encamped on the lake shore south of Huron street. The men went about in a business way, examining the government plats in the land office, and having ascertained by all means in their power where lands well timbered and watered could be purchased, they entered lands bounding on the Milwaukee river, between Milwaukee and Washington (later Ozaukee) counties. A small number remained in the village [probably Milwaukee is meant], but the most of them employed themselves without delay in clearing and cultivating lands. The men immediately declared their intention to become American citizens, every man signing his name to his petition, to the number of seventy in one day."*

The majority of the immigrants, over three hundred people, and probably those still possessing some means, went to Mequon and there formed the Freistadt colony, a name chosen, no doubt, to commemorate their new freedom; some settled in Cedarburg also, while a few remained in Milwaukee.†

These settlers were from Pomerania, chiefly from the district of Stettin and from Kamin an Greifenberg and the neighboring country.

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* Buck's Pioneer History of Milwaukee, p. 181; and an address by Judge Miller, p. 265.

† Koss "Milwaukee," p. 103. "In der Neuen Heimath." Eickhoff, 372.

Farming and stock raising are the chief industries of this country and the greater part of the land, about 60 per cent.,[*] is held by large land owners. Stettin is said to be the center of one of the best farming communities in Pomerania.[†] The Wisconsin settlers were chiefly farm-laborers and handicrafts men, and, accordingly, well adapted to pioneer life. They bought nearly all of the western half of the town of Mequon, where they built log houses and improved the land. Capt. Von Rohr had come with them, and during the first year he conducted their services until the arrival of Rev. Krause from Buffalo, who was their first pastor; immediately on his arrival a log church was built on section 19. In the Milwaukee Society services were held in a house built by a fisherman on land given him by Byron Kilbourn, near Chestnut street. It was a very solid structure, built in true German style of panel work and clay filling. They had no pastor, but the teacher Luck held services, while Rev. Krause came occasionally from Freistadt.[‡]

In 1843 another large immigation followed from Pomerania, from the neighborhood of Stettin and the cities of Kolberg, Treptow and Kamin, on the Baltic, and also from Brandenburg, from the country lying between Küstrin and Wrietzen on the Oder. Rev. Kindermann acted as their leader. He had been directed to the Pomeranian churches by Rev. Grabau during the earlier period of the persecution.[§] Others continued to come until 1845. It was the reports of the earlier emigrants, who were their friends and acquaintances, that led them to Wisconsin.

The cause of this emigration also was religious persecution, which had not yet ceased, though it was abating.[‖] But there were other causes as well. Differences had sprung up in the Lutheran church in Germany over the question of church government. The decrees of the synod were that in disputed questions of doctrine, the majority of votes should decide. Against this one party protested and claimed that the only ultimate authority was the Scriptures. To this party, which was the weaker, Rev. Kindermann belonged. To avoid unpleasantness, therefore, they decided to emigrate with those of like mind.

This company, too, had formed a common treasury to which the wealthier members contributed from 15 to 20 per cent. of their means to assist the poor, both in the passage and in purchasing land. It was expected that the money would be returned with interest, but in many cases this has not been done and the creditors have overlooked it.

Of this second body of immigrants, altogether about four hundred families, some remained in Milwaukee and joined the first comers in the

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[*] This includes the estates containing 600 morgen (acres) and more.

[†] Brockhaus Conversations-Lexicon, article, "Pommern." *Also* Schönberg's Handbuch der Politischen Oekonomie. Auflage 2, p. 962.

[‡] Koss, Milwaukee, p. 103.

[§] Life of Grabau, p. 29.

[‖] Separate worship was allowed by King William IV, in 1846.

neighborhood of Chestnut street, but the majority went to the farms. Kirchhayn, Washington county, and Lebanon, Dodge county, were chosen for settlement. Lebanon was chosen by the advice of their countrymen, J. Grünhagen, one of the earlier immigrants to Milwaukee, probably for its situation on the Rock River. Seventy-eight families settled here in the years 1843 and 1844. These were the people from Stettin and Brandenburg, while those from the Baltic lands settled at Kirchhayn.

Rev. Kinderman became the pastor of the Kirchhayn people, while at times he held services for the Lebanon community. For a year or two the settlers in Washington county suffered great privations; their land was heavily wooded and it took time to make it productive. Lebanon was more open and easier to cultivate. "Within fifteen years," says Mr. Blumenfeld, of Watertown, "the country became a garden, and to-day it surpasses most towns in its high state of cultivation." Both the communities by their industry and thrift, have been successful. There has been a marvelous change in the condition of these people from that of poor farm laborers, in most cases, to that of independent proprietors, almost all well-to-do farmers.

Between 1850 and 1860, a number of the early setlers went from Freistadt, Cedarburg and Kirchhayn, to Sherman, Sheboygan county, and Cooperstown, Manitowoc county. Land was cheap and plenty in the northern counties and there again they formed prosperous settlements.

The large Pomeranian and North German element in Wisconsin is undoubtedly due in great measure to the early emigration of the Old Lutherans to the state. Through their reports to friends and relatives in the Fatherland, many have since followed them and either joined the original communities or spread out into adjoining towns and counties. Moreover, in 1853, Capt. von Rohr and Rev. Grabau made an extended tour through Germany, especially through North Germany, and by their conversations and reports about the success of their countrymen in Wisconsin caused the majority of the Lutherans to settle in this state. Emigration from the northern countries had scarcely begun at that period but since 1870, Pomerania, Prussia and the adjoining countries have furnished the greater part of the German emigration, of which Wisconsin has received a large share.

But these early settlers were not only the first body of German immigrants to Wisconsin; they were also the beginning of the Lutheran church in the state.

Freed from state support and government restraint the Lutheran church has grown marvelously in this country. One indication of its growth is its large membership;* another indication is the variety of creeds that have developed, shown by the large number of synods of

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* According to Prof. Ernst there are 200,000 Lutherans in Wisconsin.

which there are five in Wisconsin representing differences of creed more or less fundamental. In these original communities questions of church government and religious belief caused divisions, through which the Missouri Synod and others were able to establish separate churches.

Between 1840 and 1850 the two synods of Buffalo and Missouri were formed; the one by Rev. Grabau, the other by ministers from Saxony. Soon a controversy arose between them on the question of the calling and ordination of the clergy and the relation of the minister to his society. Rev. Grabau held that a minister must be called according to the old church ordinances, and that the society must obey their minister in all things not contrary to the word of God, while the Missouri Synod held more Congregational views.* In this controversy Rev. Grabau was supported by Rev. Kindermann, Rev. Krause and deputies from Milwaukee who signed themselves "The Lutheran Synod of the church emigrated from Prussia."†

In Milwaukee, meantime, they were still too poor to hire a pastor and Rev. Krause had come from Freistadt every six weeks, but the journey was long and expensive, so he called upon the 150 communicants to pay each three cents a week for twenty weeks to buy him a horse and wagon, but the tax appeared too large to them and they refused his request. The demand was doubtless somewhat arbitrarily imposed, Rev. Krause being a man of the extreme type of clerical dignity. The society was severely rebuked by him, and was finally refused admission to the communion until they recognized their sins and made public confession, but the difficulty only increased and finally a large part of the society withdrew and joined the Missouri Synod, which allowed more self rule. The separated society was supplied with a pastor from Missouri and formed the nucleus of the later Trinity society, the first of the numerous churches in the state belonging to that synod; the remaining element formed what is now the St. Paul's society, in Milwaukee, belonging to the Buffalo Synod.‡

In the Lebanon community a controversy arose in 1847 on the subject of worldly music which caused one party to form an independent organization. Later in the same church the use of the private confessional was discussed, and again in the Milwaukee church.‖ The demand for the general confessional in its place caused the disuse of the private confessional in nearly all the churches after a few years.

There questions indicate an activity in the societies, partly the result of new conditions and the union of people from different communities in Germany, and partly the result of their recent experiences. In the

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* Wolf's Hist. of the Lutheran Church in America, p. 413.

† "Hirtenbrief des Herrn Pastors Grabau zu Buffalo vom Yahre, 1840."

‡ Hist. of Milwaukee, by Frank A. Flower, p. 924; and Koss,' Milwaukee, p. 137 seq.

‖ Bericht des Nordlichen Districkts der deutschen Evangel. Luth. Synode. von Mo., Ohio, u. a. Staaten 1855 and 1858

Lebanon community, it is said that each family owns its set of Luther's works and is familiar with theological questions. It is not strange then that there are six churches there with three pastors, of whom one is independent, another belongs to the Iowa Synod, and another to the Missouri Synod.

In Kirchhayn, Cedarburg and Freistadt also, in 1855, we find besides the churches belonging to the Buffalo Synod other societies belonging to the Missouri Synod.* Such divisions are not infrequent as the result of an unusual mental and spiritual activity, as for example Germany itself in Reformation times and England in Puritan times.

While the other synods have increased rapidly in numbers in Wisconsin and other states, the Buffalo Synod has remained comparatively isolated and small, owing to its very conservative character, and its rigid adherence to earlier doctrines. The use of the private confessional is still preserved in its churches, while its doctrines adhere to the old Saxon and Pomeranian church ordinances. The synod has but five churches in the state and these are all the original communities who emigrated between 1839 and 1845. They are Milwaukee (St. Paul's), Cedarburg, Freistadt, Kirchhayn and Sherman. The Cooperstown church, though belonging to the Wisconsin synod, keeps the doctrines and forms of the Buffalo synod.

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* Bericht — 1855.

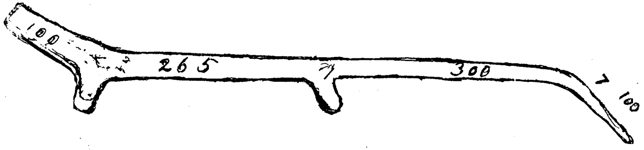
THE CLAN CENTERS AND CLAN HABITAT OF THE EFFIGY BUILDERS.

BY STEPHEN D. PEET, PH. D.

The animal effigies of Wisconsin are very interesting specimens of the handiwork of a people who have passed away. Who this people were, is at present unknown. They were, however, remarkable for one thing—their skill in imitating animal figures and especially in molding massive imitative forms out of earth and raising bas-reliefs above the surface so that they could easily be seen and recognized. Nowhere on the face of the earth are there so many of these effigies as here, and nowhere else can we learn as much about the effigy builders. There are, to be sure, a few effigies in the state of Ohio which, like these in Wisconsin, are molded from the soil. They are as follows: The Great Serpent in Adams county, the Alligator mound, and the Bird mound in Licking county, and the animal effigy in Scioto county, near the mouth of the Scioto river. The writer has discovered also a massive serpent effigy near Quincy, Illinois, and other gentlemen have discovered turtle and animal effigies, both in northern Illinois and eastern Iowa, though these probably belonged to the same system with the effigies of Wisconsin, stray specimens which were built beyond the borders of the state. Other than these, no effigies made of earth have been discovered anywhere on the continent. There are, to be sure, effigies made of stone in various parts of the country, as follows: Two in the shape of birds, discovered in Georgia and described by Col. C. C. Jones, who is one of the most skillful archæologists. Several in the shape of serpents, turtles, buffaloes and human form in Iowa, described by Prof. John Todd and Mr. T. H. Lewis. The figures of birds, turtles and nondescript creatures may be frequently seen inscribed upon rocks. Marquette, the missionary, saw one such near Alton, Ill. Jonathan Carver saw others in the caves in Minnesota. Rev. Edward Brown described those in West Salem, Wisconsin. Mr. T. H. Lewis has made a study of those found in the caves of Iowa and Minnesota. It may be said, however, that the effigies made from earth, notwithstanding the havoc made with them by the relic hunter and the farmer, have proved about as enduring as those made from stone, and no more liable to be marred and destroyed than are the inscriptions in the caves. This makes the responsibility of the citizens of the state all the greater. The effigies of Ohio are some of them to be preserved by especial enactment. The serpent effigy has been purchased and the ground about it laid out in a public park. No public movement has, however, taken place in Wisconsin, which looks toward the preservation of these most interesting monuments. They are rapidly disappearing. At the present rate of destruction, it will not be long before they will all be gone beyond recovery. When an effigy has been destroyed it is impossible to restore it. If it is reconstructed it has a modern look to it and lacks the peculiar air and grace which a native hand alone could give. The touch of the white man's hand is different from that of the mound-builder. It would be useless for him to attempt to reconstruct these animal forms.

Many things have been impressed upon us from the study of these effigies, some of which we have already embodied in the work on Emblematic Mounds which was published in 1890. Other things, however, have been brought to light by later explorations and to these we would now call attention:

I. In reference to the imitative skill of the effigy-builders, it is well known that early and rude races had this in a remarkable degree. We need only to go to the cave-dwellers of Europe to be convinced of this. Here we find the mammoth, the reindeer, the horse, and many other animals plainly drawn on pieces of ivory. They are excellent imitations and show that the early races excelled in this. We do not, to be sure, recognize in these the religious feeling which was exercised in erecting effigies on the soil of Wisconsin. There are however inscribed figures on the cylinders which have come down to us from the early historic times, which have more of this religious symbolism embodied in them. We do not know that these figures are totemistic in their design, but they are symbolic at least and are wonderful imitations. Let us take the cylinder that belongs to Sargon, 3300 before Christ. Here we find Izdubar watering the sacred oxen. The oxen have wide-spread, branching horns and small bodies — resembling Texan cattle. The human figures have strange, wild faces and shaggy hair and resemble Scythians but the drawings are excellent, the muscles are plainly seen on the oxen, the expression in the faces is striking, and the water which flows from the vessels is very like water. The effigies of Wisconsin are probably not as old as these figures from the caves of Europe or from the mounds of Chaldea, but they show the same imitative skill. Let me illustrate this: There is an effigy on the east bank of Lake Mendota but two or three miles from the capitol which represents a deer in the attitude of jumping. (See plate XII.) The deer has the head partly thrown back, the rump thrown up, the hind legs drawn toward the body very much as any deer would jump. An instantaneous photograph could not take the attitude better than did these native artists. The effigy comes to its place remarkably well, when the meas-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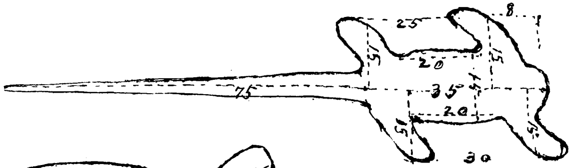
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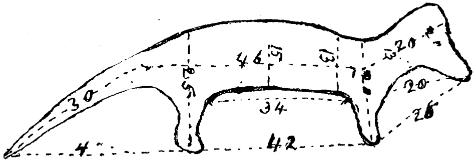
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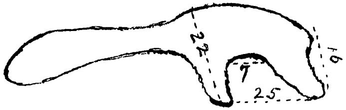
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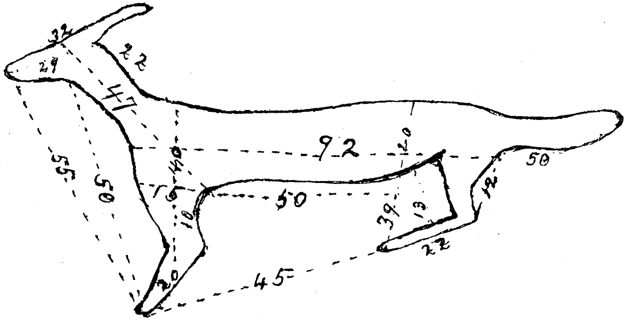
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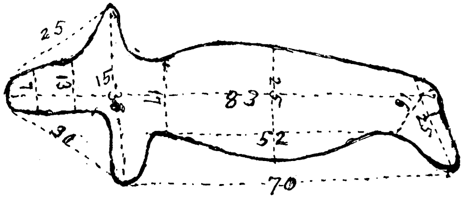
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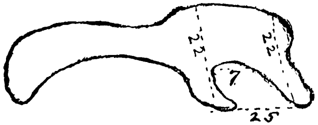
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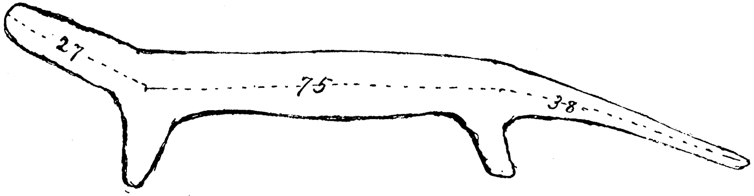
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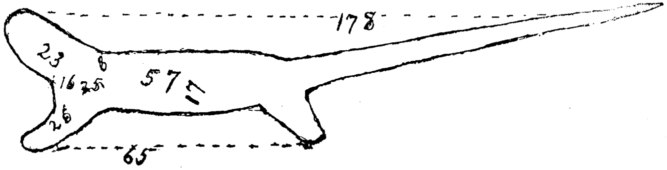
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urements are taken, and the lines drawn according to a scale of inches. The eye is useful in determining the animal intended but the platting brings out the attitude more perfectly. Take another instance: There are two animals north of Buffalo lake, not far from Crooked lake, which resemble squirrels. The platting of these effigies brings out the fact that they are not squirrels at all but raccoons. We find in them both nearly the same measurements, but as the lines come out on paper we find the crooked legs, the small head, the high curved back, the short belly and the curved, bushy tail — all of which are peculiarities of the coon. Near these coons we find a turtle — but a turtle in a most novel attitude, the same attitude which a horse assumes when he "racks," two legs upon one side thrown forward, two on the other side turned back, the whole figure being distorted and twisted as only a turtle can twist. (See plate XII.) On the west side of Green lake, squirrels appear in great numbers; every one of these squirrels has a different attitude, but an attitude perfectly natural to the animal.

II. In reference to the work of identifying the animals in the effigies. A writer in the *Nation* of New York, seems to have doubts in reference to this point. He thinks it is impossible for any one to train his eye to recognize the animals in the figures and insists upon it that the surveyor and the naturalist be summoned before one undertakes to identify the animals or decide as to the intent and hidden significance of the figures. This is an old complaint but one that is too hypercritical to be heeded. We do not deny the value of the surveyor's services and stated in the very introduction to the book that the first discovery of the shape of the effigies, was made by those engaged in the work of surveying the mineral lands. We have also everywhere given credit to the gentlemen who first platted the effigies. We have frequently quoted Dr. Lapham, and have acknowledged our indebtedness to him. We have also used the unpublished notes of Mr. H. M. Canfield, of Baraboo. This gentleman seems to have been correct in all of his observations. We have found from experience that the eye does become trained, so that it takes in large figures, and one may come to recognize the animal intended even before the measurements have been made. This, however, must always be subordinate to the surveying and every observation must be verified by measuring and platting.

The hidden significance of the effigies can not, however, be given by surveying. This comes to the mind only after a long, close study of the effigies in connection with the very locality where they are found. They must be compared with one another and classified. The totem system also of the wild tribes must be studied and then taken as a key into the field and applied to the different groups and collections of groups. We do not say that the totem system as it is now known will solve all the problems, for there are many things which baffle us, notwithstanding the application of this system. We find ourselves on the borders of an unknown realm, so much lies beyond us that we feel that we have hardly passed the rudiments, still we are sure so far as we have gone. It is possible that the effigies are myth bearers as well as totems, and that we shall need to know the myths before we can fully explain the figures. Picture writing may, also, have been practiced in the effigies, for there are groups of mounds in which the animal figures are so related to one another that it would seem as if there was a pictograph on a large scale,—these, however, are few and perhaps we shall be able to explain them in some other way. There may be other escoteric systems and various sacred mysteries embodied in the effigies. Possibly a transmitted symbolism will yet be discovered. To illustrate: There is a figure of an owl, with its projections above the head, making it resemble the horned owl. The eyes of the owl were not in the head but were under the wings and were composed of two small circular ponds of water. (See fig 1.) This effigy is found near Merrit's Landing. The whole figure taken together makes a symbol which is very common in America. The symbol consists of the eyes and nose of the divinity, and is found in Mexico and Central America as well as in the mound-builders region. The same symbol was found by Schlieman, in Troy.

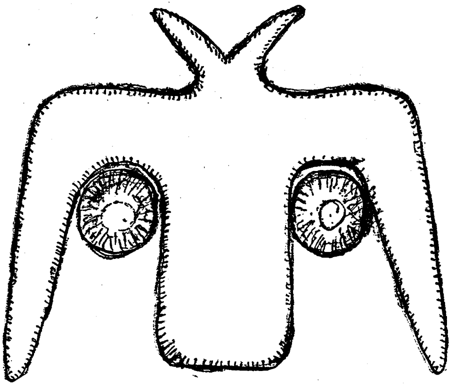

FIG. 1.—Horned Owl near Merrit's Landing.

III. Location of the clans. In the book on the emblematic mounds, we stated that there were various clans whose habitat could be easily bounded; within that habitat all the processes of clan life could be recognized in the effigies. We stated that the turtle clan was located on the Rock river and extended from Lake Koshkonong above Janesville, through Beloit and Rockford to the mouth of the Kishwaukee river; possibly Lake Geneva should be embraced within the bounds of this clan. We located, also, the panther clan on the Fox river, made it to extend from Milwaukee to Racine to the state line, and embrace the large group of mounds near Big Bend on Fox river, and including another group near Burlington on the same river.

The wolf clan we located on the Milwaukee river. The raccoon clan on the Sheboygan river. This fixed the map of the southeast part of the state. The southwest part of the state was, however, uncertain. Since the book was published we have visited this part of the state and have passed up the Wisconsin river a second or third time, filling in the links, and are now prepared to give the chain of clans which stretched from the mouth of the Wisconsin river, up through to the Dells, and from the Dells across to the Fox river and from the Fox down to its mouth. This is the old historic waterway, but it was occupied in prehistoric times. We begin in the southwest part of the state. Our first point is at Potosi, an old mining town. Here we identified two serpent effigies and a panther effigy. The mounds, however, here are mainly long mounds and stretch in lines along the summits of the narrow bluffs—very few effigies among them. (See fig. 2.) Cassville was the next point. Here we discovered on the estate which formerly belonged to Gov. Dewey, and now belongs to Gen. Newberry, of Chicago, a large number of long mounds. There is a large group of burial mounds on the bottom land opposite the picturesque ruins of Gov. Dewey's house.

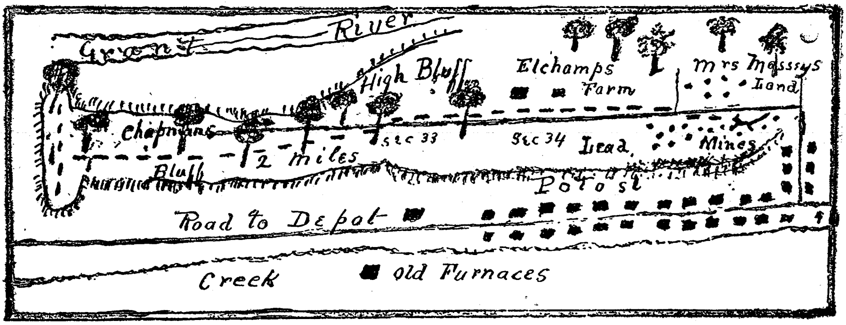

FIG. 2.—Line of Mounds near Potosi.

Passing up the Mississippi river, we come to the mouth of the Wisconsin river. Here we find the bear or buffalo upon one side and the swallow upon the other. Passing up the Wisconsin we come to Boscobel. Here through the politeness of Dr. Armstrong, we were able to visit several groups both west and east of the village and to fix the limit of the swallow clan. The group which marks the boundary of this clan is situated near Port Andrews, and is quite a remarkable group. It consists of a line of swallows over a mile long. (See fig. 3.) The swallows are on the slope of the hill near the bank of the river and underneath the rocky cliff which is here very high. The road runs along the edge of the cliff, and overlooks the land where the effigies are. They can be plainly seen from the road and are very interesting and beautiful though they are fast disappearing under the plow. There is one swallow here of which we shall speak hereafter. It is at the end of the line of swallows but is placed by itself on a knoll, and so surrounded by long mounds as to be protected on three sides, constituting a sort of enclosure by itself. East of this, in the neighborhood of Muscoda we find the eagle to be the common emblem.

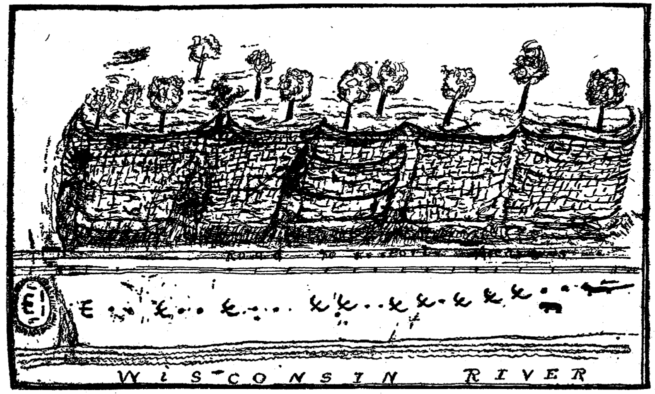

FIG. 3.—Line of Swallow Effigies near Port Andrews.

The eagle clan appears to have been a large clan. It extended from near Port Andrews, up through all the towns on the Wisconsin river and as far east as Sauk City and even extended over the water-shed, and left its totem on the banks of the four lakes at Madison. Mr. S. Taylor was the first to recognize the eagle, but he said nothing about the eagle clan and did not follow up the subject in this way. In fact all the early Archæologists were successful in their work of identifying particular birds and animals, but did not undertake to trace the clan emblems or to study the totem system. The eagle effigy, discovered by Mr. S. Taylor, at Black Earth, marks the western extremity of this clan. The eagles which, in company with Prof. F. W. Putnam, we discovered at the Dells, may have marked the eastern extremity, though the center of the clan habitat proper was in the vicinity of Eagle township. We notice that there is a difference in attitude of the eagles. At Muscoda there is a bird effigy which is about 1,000 feet in length with the wings straight out. We also found about twenty eagles with their wings partly folded in the spread eagle attitude. At the Dells of the Wisconsin and near Sauk City, the eagles have their wings in a straight line, exactly as they are on the asylum grounds north of Madison. At Honey creek there are two eagles near a game drive, and near the game drive two elks with a foe watching the elks, but in this same locality we discovered several swallows, showing that the swallow clan came into the territory of the eagle clan and placed their clan effigy on the same ground. The Eagles seem to have been great hunters, for there are a great many game drives in their territory—the elk and the moose being very common. Next to the eagles were the mink—the same clan that we have referred to before. This clan seemed to have had its center in the neighborhood of Baraboo, but it extended south across Sauk Prairie to Honey creek, east to the four lake region, north to the neighborhood of Portage and northeast to Buffalo lake. There is a group of effigies near the stone quarry two miles west of Madison, in which there is a large elk, a mink, and an eagle. There is another group near Merrill's Springs, in which there are two buffalos and an eagle, but no mink, and half a mile east, two eagles, a wild goose, a wolf and several animal effigies. The mink is not common in the four lake region, but is very numerous about Baraboo. The raccoon is another clan. This was located northwest of the mink clan—in Adams county and Juneau county. The raccoon is a very interesting effigy. It is difficult to measure and to plat, but when it is platted, comes out very beautifully. The wonder is that the effigy builders could have made it so correct. They were much better imitators than the ordinary white man. The individual who has made the work a study sees more skillful molding of animal forms than he is able to exercise in delineating them and is led to go beyond the critics, especially if they are critics who have never seen these imitative forms.

The clan east of the mink was that of the squirrel. Their habitat was very extensive. It reached from Buffalo lake across Green lake to Winnebago lake, and occasionally visited Horicon lake, even to the headwaters of Milwaukee river.

IV. The manner in which the clans marked their boundaries is another point. The effigy builders were evidently hunters, but they were hunters who seem to have carried this totem system to a great length. We find clan totems present everywhere and are able to recognize the clans by the effigies. A preponderance of one particular animal or bird over all others will be so great in one region, that it becomes a certainty that this was the clan emblem. We can fix even the habitat of the clan, by this means. Having entered into the region, we first ascertain the preponderating effigy, then follow this to the limits, until we find a change to some other. Within the bounds the clan totem appears not only in the villages and centers but near the game drives, and near temporary encampments. We ascertain by this means all about the clan. 2. The clan totem is not often carried beyond the habitat but appears near the boundaries of other clans. In such cases the effigies which embody the totem will be much larger than nearer the clan center. There may have arisen at times disputes as to the hunting grounds. This would lead the clan which claimed the hunting ground to make its totem specially conspicuous. 3. We find also, that the emblems which are placed on the borders between two clan habitats are not only very large, but they seem to be associated with all the animals which would naturally be hunted; the moose, elk, buffalo, bear are grouped together, and the clan totem placed in the same region.

We now take up the illustration of these points. Let us begin at Merritt's Landing. (See fig. 4.) Here there are two or three very large mink effigies,—one of them 700 feet long. It is so long and so level that the farmer who owns the land has placed his gateway at the head of the mink and drives to his field on the body of the mink, the roadway being open where the effigy is, but a second growth of timber comes to the very edge of the mink on either side. This mink is nearly as long as the whole drove of animals, the group on the edge of the lake being 1,000 feet and this 700 feet long. Another mink near by measures 450 feet.

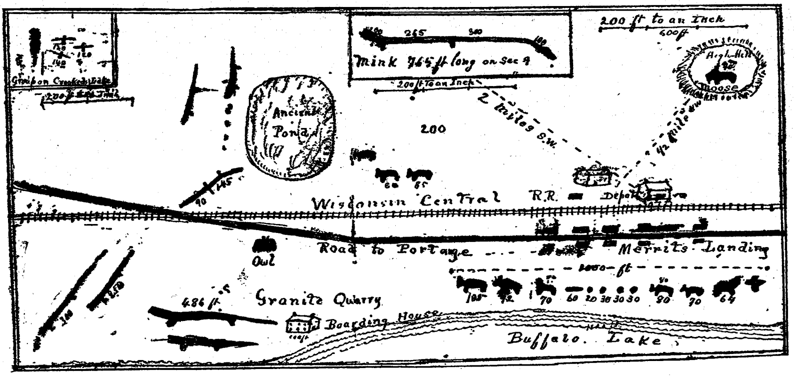

FIG. 4.—Group of Effigies at Merritt's Landing.

These effigies mark the border of the habitat of the mink clan. This clan extended from Sauk Prairie, through Baraboo across the portage of the Wisconsin and Fox rivers to the North side of Buffalo lake. On the south side of the lake about ten miles to the east of the mink clan the habitat of the squirrel clan began. Both clans seem to have had their hunting grounds on this lake. The elk, buffalo, moose, were the animals which they hunted. There are many elk effigies on the north side of the lake but the mink effigy is associated with them, mink effigies being found, also, west of Buffalo lake, near the head waters of the Fox river. Squirrel effigies extend across to Puckaway lake on the north side but do not extend west of Buffalo lake. The squirrel clan also hunted the elk. There is a group of squirrel effigies near Montello but there is an elk effigy surrounded by squirrels, and everything in the group indicates that it was the hunting ground of the squirrels.

There is one contrivance which the squirrel clan adopted that is worthy of notice here. They made two squirrels on a large scale, twisted the tails of the squirrels around over the back, very much as it is twisted in the squirrel effigy on the asylum grounds opposite Madison, but between the tail and the body of each squirrel, they dug a large pit in the sandy soil and so made a trap for the animals which they would drive from the forests towards the lake.

It is probable that they placed timber or brush, palisades or fences around these traps but the squirrel effigies and the pits are all that are left. The mink clan placed a moose on the highest hill that they could find and from the top of this massive effigy could watch the squirrel clan chase their game; for the two groups are not so far apart but that on a clear day, they might recognize their presence or at least they could exchange signals with one another. We are convinced that the clans were friendly for these signal stations are scattered all over the state; but the border lands between the clans may have been common property.

V. We now turn to the clan centers. The question which arises here is, whether there were any clan centers which can be recognized. It is well known that every clan has its central organization, its village site, its council house, its burial place, frequently its place of sacrifice, and its own place of assembly. The hunters did not differ from others in this. They had game drives and frequently encamped away from their villages, but there was among them a clan organization and a clan center. It has been therefore a purpose with us to discover the clan centers. We think we have done this in some cases, but in others are somewhat doubtful. In the book on Emblematic Mounds we have spoken of the villages of the effigy builders, one located at Big Bend, another at Waukesha, both on the Fox river, another at Racine. The village at Racine was situated on the summit of an isolated bluff and was surrounded by conical mounds and panther effigies. There were lookout mounds on adjoining hills and garden beds in the valley below and a large number of burial mounds on a hill opposite the village. The village at Big Bend was surrounded with oblong mounds and panther effigies. Opposite this, on a high bluff, was an altar mound and some two or three miles west was a game drive and another two miles north of the village, both of them abounding with panther effigies. Caches, or pits, for storing corn were numerous near this village. The enclosure at Aztlan may have been a clan village or it may have been a general capital or a place of general assembly for all clans. Mr. W. H. Canfield has located the village of the Mink clan, near Baraboo, and has spoken about the council house. He represents this as a sort of circle or enclosure, which is surrounded by a large number of animals, the mink being the most numerous. If we take this as our clue, we should place the council house of the Turtle clan on the east side of Lake Koshkonong, for the group here resembles that at Baraboo in many respects.

We discovered at Green lake, a circle or ring of earth in the midst of a large number of effigies, the fox, eagle, wild goose, but the squirrels largely preponderated. This ring was situated not far from the village, the village being near the water, with the squirrels guarding its gateways, but a council house on the hilltop remote from the water. One peculiarity of these so-called council houses, we do not understand. We find around them so many effigies which are different from the clan emblems, a strange mixture of animal forms. In Catlin's Indians is a description of a medicine lodge of the Mandans. The medicine man sits in his lodge and summons all the animals which are the totems of all the tribes. We have the same picture in the effigies. In one place at Lake Koshkonong, we have the eagle, turtle, the fish, pigeon, woodcock, the blue heron, the wolf, the lizzard and many other animals. At West Bend we have the lizzard, the wolf, wild cat, coon, snake, and about a dozen squirrels. At Baraboo we have the elk, buffalo, bear, wolf, eagle, coon, fox, and a large number of mink. At Beloit, the panthers, wolf, bear, pigeon and several turtles. All of these are grouped together in a very remarkable manner. We call these council houses, but we do not understand all of the features that are embodied in the group. This is the point which we confess to be obscure, but think we are on the borders of a constructive, rich field, but do not pretend to have fathomed the subject.

VI. The citadels or sacred enclosures will be considered next. Here we draw a distinction between groups of effigies, in the midst of which are the circles or earth-rings which we call council houses and the long lines of effigies at the end of which are what we call "sacred enclosures," but which Mr. S. Taylor called "citadels." These are lines of long mounds which have no "citadels" or "inclosures" connected with them. These are placed "generally," at the summit of long narrow bluffs, on high land, and were probably used either as screens or hedges or barriers to stop the flight of wild game, to drive them into narrow openings, or as elevated roads for hunters to run upon when they were chasing the game. They are in the most sightly places, and are elevated to a uniform height and run along the summit of the bluff for many miles. There are very few effigies connected with them. They are different from the lines at the end of which are the citadels. The "citadels," so called, are nothing but little clusters of effigies, five or six in number, so arranged that they form a sort of enclosure. In the center of the area, there is always to be seen a mound of some kind, either a high lookout mound, or an effigy. There are many such citadels, at least one to every clan habitat. A good illustration of this is found in the isolated clusters in the Port Andrews group opposite Boscobel. (See fig. 3 and 5) Here the effigy is a swallow—a totem of the clan which lies to the west. It is surrounded by long mounds, and forms an unique cluster. It is at the end of a long line of effigies, all of them swallows. Another example is found near Muscoda. The group is here prominent and forms the top of the principal mound; occupying the center of the enclosure, may be seen at least 100 elevations, which stretch about 400 yards to the westward. The effigies which form the walls to this enclosure are eagles, the eagle being the totem of the clan at Muscoda. A similar cluster has been described by an old settler living near Merritt's Landing, as having formerly existed on a knoll not far from his house. The effigies surrounding the enclosure were mink, their tails extending out long distances, like the spokes of a wheel, their heads toward the center. We have said that the mink was the totem of this region. We would say also that one of the groups of effigies of this place consisted of a long line of elks which stretch along the borders of the lake. The so-called citadel on the top of the hill was not far from the end of this line.

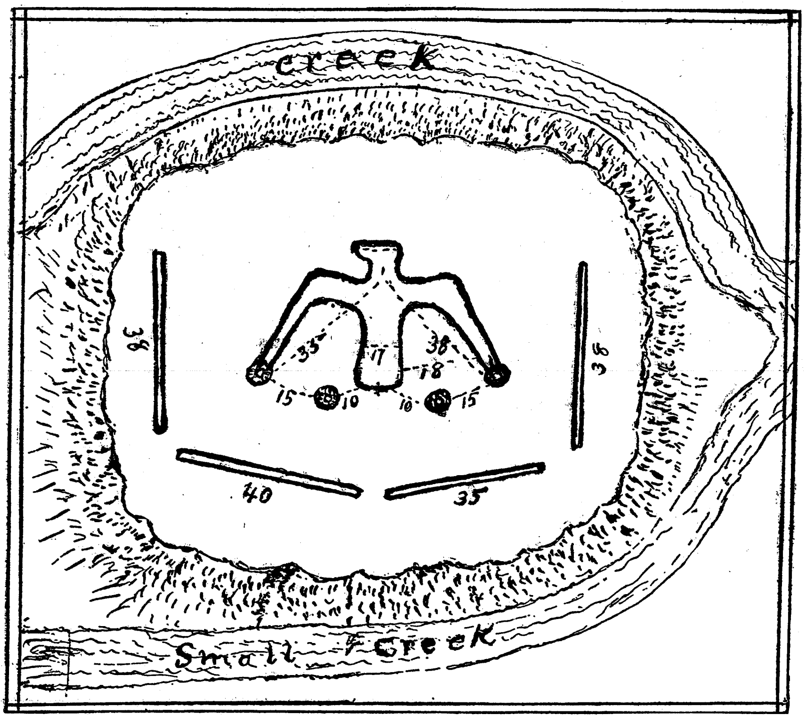

Fig. 5.—Sacred Enclosure near Port Andrews.

Mr. R. C. Taylor discovered a long line of "bear effiigies" near the "Blue Mounds" in Dane county. In the line was the man mound. The line was about one and one-half miles in length and contained six effigies of bears, six oblong mounds and one effigy of the human figure and a small circle. There is a group on the south shore of Lake Mendota near Merril's Springs. Here there is a short line of burial mounds with the effigy of the eagle at one end. At the east end two buffalo effigies, three oblong mounds, arranged around a central lookout or conical mound. This we should hardly call a citadel though it illustrates how the effigies are sometimes clustered or grouped around a central mound.

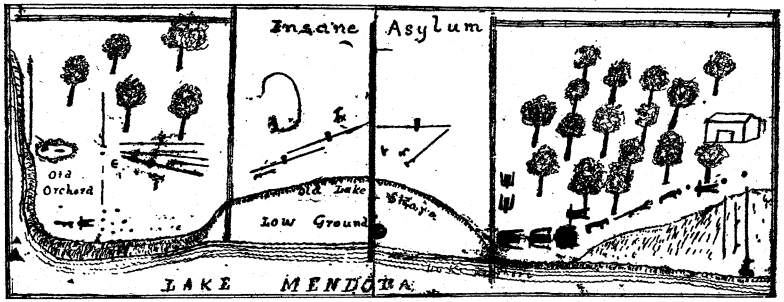

FIG. 6.—Group of Mounds on north shore of Lake Mendota, Madison, Wis.

The group on the north shore of Lake Mendota differs from this and from nearly all other groups which we have visited. (See fig. 6.) Here the effigies are neither in a line with a citadel at the end nor are they grouped around a central circle with the "council house" in the circle but they are arranged in a row with the heads of many of them toward the lake.

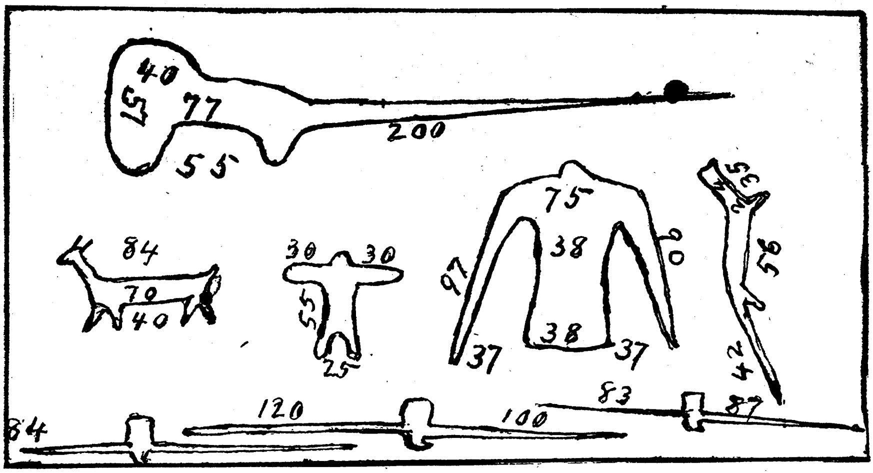

FIG. 7.

There are in this entire group from 40 to 50 mounds — many of them effigies, but no one class of effigies preponderating. At one end is a very large animal which we call a panther, next to this is a mink, at the end of the mink, a man mound, near this a buffalo, next the fox, then the bear, and another man mound and three or four pigeons of gigantic size. (See fig. 7.) In the front of the asylum three eagles, a wolf, a bear, a fox and a squirrel. West of the asylum we find three long mounds with an effigy in the midst on the side hill — on the top of the hill an animal with a very long tail, possibly a squirrel, another with a short bushy tail, perhaps a raccoon, another man mound, and a large cluster of burial mounds, one of which contained an altar. These effigies do not bear the right proportion to one another, for the panther is some two or three times larger than the buffalo and the pigeon is even larger than the panthers. The fox is very slender but the two man mounds are even smaller than the fox; the deer is very small, not an eighth as large as the eagle, but the squirrel has a tail 300 feet long, which is really the longest tail we have anywhere seen.

Our explanation of these two classes of works is that one (the citadel) embodied the council houses or assembly places of the clans, the other the houses of the chiefs or clan rulers. This is conjectural but satisfies the demands of the problem better than any other conjecture. We throw it out merely as a suggestion, but would call attention to the different classes of mounds as they are brought before us on this general map. The habitats of the different clans may certainly be ascertained by the totems. We think also that the clan centers can also be ascertained and the different places where clan life embodied itself can be identified. Their villages with their game drives, burial places, sacrificial places, dance grounds, assembly houses, council houses, and the houses of their chiefs, all can be located by the study of the effigies.

THE LIMONENE GROUP OF TERPENES.

BY EDWARD KREMERS.

The following historical study was undertaken with the desire to throw some light upon the history of the terpenes. This class of compounds has been of interest to chemists ever since organic chemistry may be regarded as a science. Year after year the material accumulated until by the beginning of the last decade it constituted a special lumber-chamber of chemical literature. The reasons for this disorder are of a varied character. The thought that every volatile oil contained its peculiar terpene, when such was present, for a long time seems to have prevailed in the minds of chemical investigators. Another grave fault is to be found in the fact that one investigator often gave but little or even no attention to the researches of others. This brought about serious confusions in the chemical nomenclature, which in turn gave rise to misunderstandings everywhere. The reason why, even in later years, so little could be done to clear up the subject is to be sought in the fact that for the most terpenes, no characteristic reactions were known. Since at present, at least some systematic knowledge has been acquired, it may not be without interest to look back and see who has identified himself with the problems under consideration, who has aided in their solution and who has retarded the same. In the course of years the amount of material has accumulated to such an extent that a survey of the same is a difficult matter, even for the person who has made a special study of the subject. In fact an understanding of the Limonene group of terpenes became possible only after Prof. Wallach, in 1888, had demonstrated the relations existing between the members of this group.

For the better understanding of the subject the following explanatory remarks may serve as a brief introduction. The limonene group of terpenes consists of three hydrocarbons: the optically active, dextrogyrate and lævogyrate limonene and the optically inactive dipentene. Whether the inactive compound resulting from the mixture of equal parts of the optically active components is identical with dipentene still remains an open question. Suffice it is to say that all crystallizable derivations of such an optically inactive mixture are identical with the corresponding

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* These notes are translated from a series of articles published on this subject by the writer in the "Pharmaceutische Rundschau" of 1891 and 1892.

dipentene compounds. The two physical modifications of limonene can add one molecule of hydrogen chloride without loosing their optical activity. The additions of a second molecule, however, renders them optically inactive, they are then no longer limonene, but dipentene compounds. Pinene, the most characteristic hydro-carbon of the turpentine oils, adds one molecule of hydrogen chloride to form the so-called artificial camphor, or pinene, monhydrochloride. Under certain conditions it also will add two molecules of hydrogen chloride and thus be converted into dipentene dihydrochloride. Limonene as well as pinene can be "inverted" into dipentene. This inversion can also take place through terpin hydrate. Limonene, and pinene even more readily, will add three molecules of water to form terpin hydrate. This optically inactive hydrate is no longer either a limonene—or pinene—but a dipentene derivative. As will be shown later these inversions for a long time baffled chemical investigators, and it is but recently that their character is being understood. This knowledge, the outcome of a series of investigations by Prof. Wallach, has at last shed considerable light upon the constitution and isomeric relations of the terpenes.

THE HYDROCARBONS.

SYNONYMS AND HISTORY.

Dextrogyrate Limonene.

Citrêne — J. Dumas,[1] 1833.
Essence de citron — J. Dumas [1] & [3].
Citronyl — Blanchet & Sell,[2] 1833.
Carven [19] — Schweizer,[4] 1840.
Hesperidene — Wright Piese,[11] 1871.
Citren [19] } Wallach.[18]
Hesperiden } Wallach.[18]
Limonen — Wallach, 1884.
Citrene — Yoshida, 1885.
Rechts-Limonen — Wallach [22], 1888.

Dumas[1] stated (1833) that "Citrêne," the hydrocarbon from oil of lemon is isomeric with "camphêne," the hydrocarbon from turpentine oil, with this difference: the molecule of the former is but half as large as that of the latter. This distinction is shown by their different capacity for absorbing hydrogen chloride. He regarded the natural "citrêne" (dextrogyrate limonene) as being identical with the artificial hydrocarbon which he recovered from the hydrogen chloride addition-product (namely dipentene), and which he also designated as "citrêne."

Blanchet and Sell[2] (1833) designated as "citronyl" that hydrocarbon of the lemon oil which is capable of forming a solid compound ("festes salzsaures citronenöl ") with hydrogen chloride, and regard it as isomeric with "Dadyl" that hydrocarbon of turpentine oil which is capable of yielding a crystallizable compound with hydrochloric acid.

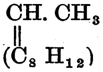
Soubeiran and Capetain (1840) distinguish for the first time between limonene and dipentene. They had determined the rotatory power of their original material (for the "essence de citron rectifiée $[\alpha]_D = 80°.916$ dextrorotatory), but found the "camphre de citron" (dipentene dihydrochloride) obtained from it, as also the regenerated "citrêne" (dipentene) to be optically inactive. The difference, they state, is the same as that between the "térébène" (o-Pinene) and the essence of turpentine (–Pinene). They also call attention to the fact that the "essence de térébenthine" (–Pinene) retains in the "camphre solide" (Pinene-monhydrochloride) its optical activity, and that "S'il est possible de supposer que l'essence de térébenthine soit entrée sans alteration dans le camphre solide, on ne peut se refuser à reconnaître que dans ancune de ses combinaisons l'essence de citron n'a conserva son état meléculaire primitif." Soubeiran and Capetain had thus recognized and pointed out the difference beeween the hydro-carbons we now designate as dextrogyrate limonene and dipentene, and had also indicated the inversion of one into the other. But, although they isolated and identified the dextrogyrate limonene from the oil of orange, they do not at all call attention to the identity of the same with that from lemon oil.

In 1840 Schweizer[4] isolated from the oil of caraway a hydro-carbon, which he designated "carven" (+ Limonene). By passing hydrogen chloride into it he obtained a dihydro chloride melting at 50° (Dipentene dihydro chloride). The hydro carbon regenerated from this compound by means of lime he regarded as unchanged carvene. Based upon his analyses and vapor density determinations he assigned to the "carven" the formula $C_{10}H_{16}$. Boiling point 173° C.

It is quite apparent from what has been stated above that the different capacity for the saturation of hydrogen chloride was regarded as chief distinction between pinene and limonene. Based upon the direct formation of dipentene dihydro chloride from turpentine oil, Berthelot[5] (1852) claimed that the distinction between turpentine oil and lemon oil, i. e., between pinene and limonene, was not at all essential. He seems to regard both as identical, though he admits a slight difference on account of the somewhat varying stability of the molecule of the two. As a further proof for the latter statement, he shows later that limonene is not as easily affected by heat as pinene[6–7].

Already in 1840 Völckel[8] had surmised the existence of a hydrocarbon besides carvol in the oil of caraway. In 1853[9] he pointed out the apparent genetic relations existing between carvol and this hydrocarbon, the so-called carvene (+ limonene). Although Völckel's formulas have long been discarded the fact remains and is of historic interest.

In 1864 Gladstone attempted to introduce order into the then already chaotic condition of the terpene literature. Based upon physical and chemical properties he classified the terpenes into three great groups. It is of special interest to note that he would regard the terpenes from sweet orange oil, lemon oil and the oil of citrus medica as identical rather than isomeric.

In 1871 Wright & Piese[11] oxidized hesperidene from orange oil (+ limonene) with chromic acid mixture, and obtained acetic acid. From this they conclude that the formula  $\begin{array}{c}CH.\,CH_3\\ \|\\ (C_8\,H_{12})\end{array}$ expresses in part "the grouping of the constituent carbon atoms." Nitric acid oxidizes hesperidene to oxalic and carbonic acids.

Two years later Wright[12] obtained from hesperidene besides acetic and formic acid a substance $C_{10}\,H_{16}\,O$ when oxidized with chromic acid mixtures. When oxidized with nitric acid he obtained oxalic acid and hesperidinic acid, $C_{20}\,H_{26}\,O_{17}$, *but no terephthalic acid.*

When a molecule of bromine is added a liquid non-characteristic dibromide is formed which when heated splits off hydrobromic acid and cymene results which is identical with the cymene obt. from pinene and "citrene" (+ limonene from oil of lemon). From this Wright concludes "that these three terpenes may all be regarded as dihydrides of cymene." The yield of cymene from "hesperidene dibromide" was 80 per cent. and from the cymene he obt. by oxidation 45 per cent of terephthalic acid. From the latter experiment he concludes that "the production of terephthalic acid "from cymene by oxidation shows that two 'lateral chains' are present; and as toluic acid is also obtainable from cymene, one of these must be methyl (since toluic acid gives rise to methyl-benzene toluene); cymene therefore is either a methyl propyl-benzene or a methyl isopropyl benzene."

As to some of these views, however, Oppenheim[13] has claim of priority. He had obtained "citrene cymol" by addition of bromine to "citrene" and then splitting off hydrobromic acid by means of anilin; also according to Kekulés method by adding iodine and splitting off hydroiodic acid with the aid of heat. In his oxidation experiments with dilute nitric acid he obtained not only terephthalic acid but also para-toluic acid and acetic acid. Neither "terpene cymol" nor "citrene cymol" therefore contain an etlyl group, but both have in para-position methyl and propyl. The formation of acetic acid makes it probable that the latter is isopropyl.

Already a year previous Oppenheim[14] had remarked that the terpenes were hydrocymols. Remarkable are, however his words which he wrote shortly after. "The fact, however, that until now para cymol has only been obtained from terpenes may well create the suspicion that even the mildest reaction according to which hydrogen may be abstracted, the action of iodine on the terpenes, disturbes the molecular arrangement of the same and causes a rearrangement of the atoms which prevents us from recognizing the original structure of the terpenes."

In the seventies Tilden introduced a new class of terpene derivatives which proved of exceeding interest and importance. His nitrosylchloride addition products and the nitro terpenes obtained therefrom afforded a better means to distinguish the hydrocarbons of the pinene group from those of the limonene group. He showed also that the terpenes from orange oil, bergamot oil and caraway oil afforded the same nitrosylchloride addition product.

With the year 1884 there began a new era in the literature of terpenes and volatile oils. Wallach had succeeded in preparing a tetrabromide[17] of "cynene" $C_{10}H_{16}Br_4$ (now Dipentene tetrabromide), a handsomely crystallizable body which melted at 124°. Soon after he obtained a tetrabromide from "hesperidene" (+ limonene), which crystallized in a very similar form, but melted at 104°. Wallach wrote at the time, "There seem to exist very close relations between "cynene" and "hesperidene," but no complete identity." In these tetrabromides we have, as it were, the key to our present knowledge of the terpenes. These two terpenes which for decades had been a stumbling block to chemists, were now characterized. The importance of these substances already becomes evident from the second contribution[20] of Wallach four months later. By means of the tetrabromide Wallach proved the presence of limonene in the fraction 175° of the following oils: lemon oil (so-called "citrene"), bergamot oil, caraway oil (so called "carvene"), dill oil, erigeron oil and in the oil of the leaves of pinus sylvestris.

Wallach showed, furthermore, that these fractions could be inverted into dipentene by means of heat (temp. of 250–270°) as was shown by means of the dipentene tetrabromide. Also by adding two molecules of hydrogen chloride and splitting off the same by heating with aniline and converting the resulting hydrocarbon into its tetrabromide.

Wallach then characterizes limonene in the following manner: "It boils between 175–177°, and possesses a lemon like odor. It produces a nitroso derivative which melts at 71°, and a tetrabromide which melts at 104°, and crystalizes in rhombic-hemiedric forms. Hydrogen chloride converts it in etherial solution into a dihydrochloride of *dipentene* which melts at 50°. Hesperidene, citrene, carvene, etc., are hereafter to be designated as limonene."

The true character of limonene, i. e. its position as the dextrogyrate member of the limonene group became apparent in 1888 when Wallach[22] recognized lævogyrate limonene as such and succeeded in the synthetical preparation of dipentene derivatives from its destrogyrate and lævogyrate components. The peculiar differences between the limonenes and dipentene as revealed in their derivatives, as also the singular position of the dipentene derivatives when compared with the optically inactive derivatives of pinene and camphene must be considered later. It is no doubt largely due to these peculiarities that our knowledge of the relations existing between the members of the limonene group was so long retarded.

Lœvogyrate Limonene.

Limonen — Wallach[2] 1884.
Citrene — Yoshida[3] 1885.
Links-Limonen — Wallach[4] 1888.

Apparently Deville[1] (1849) has first described lævogyrate limonene, without, however, recognizing its peculiar relation to dextrogyrate limonene, then chiefly known as citrene. From elemioil Deville obtained a hydrocarbon which had the constant boiling point 174°, and to which he assigned the composition $C_{10}H_{16}$. At 11° it had the specific gravity 0.849; coefficient of refraction 1.4719 at 14°C; specific rotatory power $-90°$, 30; vapor density 4.84 (calculated 4.76). With hydrogen chloride he obtained a compound to which he assigned the formula $C_{10}H_8HCl$, and of which he states: "La rotation de a camphre est nulle comme celle du camphre de citron, son isomère."

In 1884 Wallach demonstrated by means of the tetrabromide reaction the presence of limonene in the oil from pinus sylvestris without, however, paying attention to its optical properties. In the following year Yoshida[3] isolated from camphor oil a fraction 172-173° of the composition $C_{10}H_{16}$ of which he writes (p. 787): "This hydrocarbon is probably chemically identical with citrene, the main constituent of the so-called essence of lemon. The point of difference from the lemon oil citrene is its lævorotatory power, viz. $[\alpha]_j = -68.3°$, but this can be looked upon as a physical difference between the two, such cases being common among the optically active terpenes." Yoshida obtained from this fraction a "Dihydrochloride of Citrene," $C_{10}H_{16}\,{}_2HCl$ (melting point 58-59° C.), but did not succeed in making the nitroso-chloride. By the addition of one molecule of bromine and splitting off hydrobromic acid he obtained cymol, which upon oxidation yielded 40 p. c. terephthalic acid.

In 1888 Wallach[4] showed that lævogyrate limonene occurs in the oil from the leaves of pinus picaea. "The lævogyrate limonene has a constant boiling point of 175-176°, its spec. gravity was 0.846^5 at 20°, $[\alpha]_D = -105°$. Tetrabromide and nitroso-chloride clearly demonstrate the opposite character of the hydrocarbon with reference to its dextrogyrate congener.

Dipentene.

Citrêne [1] — J. Dumas, 1833.
Citronyl [2] — Blanchet and Sell, 1833.
Kautschin [3] — Himly, 1835.
Citrène [4] — Soubeiran and Captain, 1840.
Carven [5] — Schweizer, 1840.
Cynèn [6] — Völckel, 1854.
Cinæben [7] — Hirzel, 1854.
Caoutchine [8] — Williams, 1860.
Cynen [9] — Græbe, 1872.
Isotérébenthène [10] — J. Riban, 1874.
Di-isoprène [11] — Bouchardat.
Terpilène [11] — Bouchardat.
Dipentene [12] —
Terpene [12] — } Tilden.
Terpilene —
Citrene [13] — Watts, 1886.
Cynen [14] — Wallach, 1884.
Cajeputen [15] — Wallach.
Cinen [16] — Wallach, 1884.
Dipenten [17] — Wallach, 1884.

In an article "Sur la combinaison de l'essence de citron avec l'acide muriatique," Saussure[18] (1820) states that from the "muriate citré" (dipentene dihydrochloride) the hydrochloric acid can be removed *in part* by distillation with caustic lime.

In 1833 J. Dumas reports on the regeneration of the hydrocarbon "citréne" (dipentene) from the "camphre de citron" (dipentene dihydrochloride) by repeated distillation with caustic potassa and caustic baryta. He assigns to the regenerated hydrocarbon the formula $C_5 H_4$ and makes about it the following concluding remark: Si 'l est donc certain, que cette matière, qui fait presque totalité de l'essence de citron, est isomerique avec celle, qui forme de son côté la presque totalité de l'essence de térébenthine, avec cette difference, que la condensation des éléments est double dans la dernière." From these remarks it becomes quite evident:

1. That Dumas recognizes the isomerism between pinene and limonene, resp. dipentene.
2. He supposes the limonene present in the oil of lemon to be identical with the dipentene regenerated from the dipentene dihydrochloride obtained by the addition of hydrogenchloride to, and by the inversion of limonene.
3. He recognizes the fact that limonene will absorb again as much hydrogenchloride as pinene. Laboring under the false supposition that

a molecule of hydrocarbon can combine with but one molecule of hydrogen chloride, he comes to the conclusion that the molecule of limonene, resp. dipentene is but half as large as that of pinene.

Blanchet and Sell [2] (1833) obtained independently the same results and come to the very same conclusions.

In 1835 Himly [3] obtained from the products of dry distillation of caoutchouc a fraction 168–171°. Saturated with hydrogen chloride this yielded "salysaures Kautschen," (dipentene dihydrochloride) from which the hydrocarbon can be regenerated by distillation with caustic potassa and rectification over metallic potassium. The regenerated hydrocarbon was colorless, possessed a limonene odor; spec. gravity 0.8423 at 16°; boiling point 171°; vapor density 4.461. He assigns to it the formula $C_5 H_8$.

An observation of Soubeiran and Captain (1840) is of great interest, viz.: that the hydrocarbon regenerated from the *optically inactive* "camphre de citron" (dipentene dihydrochloride) is likewise *optically inactive* and is thus distinguished from the "essence de citron" (+ limonene).

Schweizer,[5] however (1840), still regarded the dipentene regenerated from the dihydrochloride as identical with the "carvene" (+ limonene) from which the dihydrochloride had been prepared.

In 1848 List [19] observed that when the "chlorwasserstoff verbindung des *Terpins*" (dipentene dihydrochloride) is distilled with caustic lime, or when anhydrous *terpin* is distilled repeatedly with anhydrous phosphoric acid a volatile oil of the composition "$C_{20} H_{16}$" is formed.

In the following year (1849) Deville [20] regenerated the hydrocarbon from the "camphre de citron" (dipentene dihydrochloride) prepared from terpin hydrate and declares this hydrocarbon dipentene to be identical with "l'essence de citron" (+ limonene). This, he states, "furnishes the means to transform the essence of turpentine into the essence of lemon." (That Deville, who made considerable use of the polariscope in his investigations, apparently gives no heed to optical properties in this case is rather surprising.)

In 1860 Greville Williams [8] in his researches on "Isoprene and Caoutchine," confirms Himly's analysis. He states further that "caoutchine" (dipentene) decolorizes four equivalents of bromine; that by the alternating action of bromine and sodium cymol is obtained, which upon oxidation yields "insolinic acid." Sulphuric acid converts "caoutchine" into a viscid oil. Small quantities of an acid "$C_{20}H_{16}S_2O_6$" are also formed from which a calcium salt, "$C_{20}H_{15}CaS_2O_6$" was made. Williams assumes that the heat effects a tearing assunder of a polymeric body (caoutchouc), and that the substances which are formed stand in a simple relation to the mother substance.

Tilden [11] in 1882 repeated some of the experiments of Greville Williams and of Bouchardat pertaining to the decomposition of terpenes at high temperatures. In an article [19] (1884) he makes the following very important claim: "There is no doubt that the di-isoprene of Bouchardat and the dipentene which I have just described, are identical with terpilene, the optically inactive hydrocarbon into which the terpenes and citrenes are convertible."

In 1886 Watts[31] showed dipentene (called by him "citrene,") to be present in the oil of the leaves from citrus limetta. He states that it resembles "citrene" (+limonene) very much, but behaves differently toward polarized light.

Bouchardat and Lafont[22] (1886) studied the action of chromic acid on lævogyrate pinene. Among other products they obtained a hydrocarbon $C_{10} H_{16}$ which boiled between 174-178°, $[\alpha]_D = -56°$ and combined with hydrochloric acid to form a "chlorhydrate de terpilène ou de citrène" which melted at 47°, (dipentene dihydrochloride). It is quite evident that this hydrocarbon consisted of a mixture of limonene and dipentene. The "isoterpenes" of Flawitzky[23] obtained by the dehydration of the so-called "terpenhydrate" (evidently mixtures of the opt. inactive terpinene with the opt. active ones,) are no doubt similar mixtures.

Bouchardat and Voiry[24] (1888) bring nothing new when they state that dipentene dihydrochloride when heated with alcoholic potash yields a "carbure terpilénique" (impure dipentene). This fact simply shows that the deplorable custom of dishing up old facts with new names has not entirely ceased[25]. In his articles "Sur l'essence d'Eucalyptus globulus"[26] and "Sur l'essence de cajeput"[27] Voiry even surpasses his master in scientific dishonesty.

In a historical study of dipentene wormseed oil (Oleum cinae) must not be left unconsidered. It constitutes as it were a special chapter in the history of this hydrocarbon. It will, therefore, be necessary to turn back and study the development of our knowledge concerning dipentene ("cynene") in connection with this oil.

In 1841 Wöhler[27] communicates the results of Völckel's analysis of the oil. He states that "it does not appear to stand in any simple relation to santonin" but consists of a substance "$C_9 H_{15} O$" admixed with small quantities of another oil." In 1853 Völckel[28] assigned to the chief constituent of the oil boiling at 174-175° the formula "$C_{12} H_{10} O$." In the following year in an article "Veber das Cynen" he treats of a hydrocarbon obtained by distilling wormseed oil repeatedly with anhydrous phosphoric acid. After successive treatment of the crude product with *sulphuric acid*, water and chloride of calcium in order to "*purify*" ? it, the "cynèn" distilled completely between 173-175°. He assigns to it the formula $C_{12} H_9$. "Das Cynèn ist demnach aus dem Wurmsamenöl: $C_{12} H_{10}$ O durch das Ausscheiden vom 1 Aeq. Wassertoff and 1 Aeg. Sauertoff als Wasser entstanden."

Hirzel[7] (1854) regards the rectified "Ol Cinae" to consist of a mixture of a hydrocarbon "Cinaeben" "$C_{10} H_8$" with "Cinaeben campher," "$C_{10} H_9 O$." The latter when distilled with anhydrous phosphoric acid yields among other products "Cinaeben."

Kraut's [29] analysis of wormseed oil (1862) would lead him to the formula "$C_{24}H_{20}O_2$," However, his vapor-density determinations bring him to the conclusion that the oil is a mixture of a substance "$C_{20}H_{18}O_2$," with little of a hydrocarbon "(probably of the formula $C_{20}H_{16}$)."

Kraut and Wahlforss [30] verify Völckel's statement in so far as the oil when distilled with anhydrous phosphoric acid yields a hydrocarbon. Their analyses and vapor-density determinations, however, lead them to the formula "$C_{10} H_{16}$." "*This hydrocarbon is optically inactive.*"

Graebe [9] replaced (1872) phosphorus pentoxide by phosphorus penta sulphide. He obtained a hydrocarbon which he supposed to be "cynen." However it must have been cymol, since it yielded terephthalic acid upon oxidation. Graebe's "cynen sulfosaeure, $C_{10} H_{15} (SO_3 H)$" when fused with caustic potassa did not yield a phenol of "cynen" but of cymol, consequently it must have been a derivative of the latter.

Faust and Homeyer [31] prepared "Cynen" according to Graebe's method and identified it as cymol by means of paratoluic acid and of cymol sulphonate of barium. They believe that there can be no further doubt as to the identity between "cynen" and cymol.

Hell and Stürcke[32] (1884) again use phosphorus pentoxide as dehydrating agent and obtain the hydrocarbon $C_{10} H_{16}$. Fuming sulphuric acid blackens it and converts only a part of it into the sulphonic acid. The barium salt is stated to be identical with the barium cymol-sulphonate obtained by Kraut from caraway oil. Hell and Stürcke arrive at the conclusion that by the action of phosphorus pentoxide upon wormseed oil "cynen" and not cymol results, but that the sulphuric acid by abstracting two hydrogen atoms oxidizes the former into the latter[34].

Hell and Ritter [35] (1884) have observed that when hydrogen chloride is passed into wormseed oil, this becomes heated and $C_{10} H_{18}$ 0. H Cl is not formed but water is split off and "cynendihydrochlorid" $C_{10} H_{18} Cl$ (melting point 50–51°) results (dipentene dihydrochloride). From this "cynen" (dipentene) can be obtained by distillation wth caustic soda and rectification over metallic sodium. These reactions are to be expressed by the following equations.

1. $C_{10} H_{18} O + H Cl = C_{10} H_{18} Cl (OH)$. [a chlorhydrin.]
2. $C_{10} H_{18} Cl (OH) + H Cl = C_{10} H_{18} Cl_2 + H_2 O$.
3. $C_{10} H_{18} Cl_2 = C_{10} H_{16} + 2 H Cl$.

About the same time with Hell, Wallach[36] began his investigations of the terpenes. In part they meet on the same ground, in part they supplement each other. However, where Hell feigned analogies to exist among terpenes or their derivatives Wallach removed all doubts and thus laid a foundation for a systematic investigation of the terpenes.

Wallach showed that the composition of the hydrogenchloride addition product of cineol $C_{10}H_{18}O$, the chief constituent of wormseed oil, is expressed by the formula $(C_{10}H_{18}O)_2HCl$. When heated by itself this compound splits off water and hydrochloric acid as expressed by the following equation:

$(C_{10}H_{18}O)_2HCl = 2H_2O + HCl + 2C_{10}H_{16}$ whereby cinene (dipentene) is formed. Cineol adds two bromineatoms to form a bibromide which is deliquescent. Water and hydrobromic acid split off and a tetrabromide $C_{10}H_{16}Br_4$ is formed which melts at 125.5°. This tetrabromide is identical with the one obtained by the addition of bromine to the hydrocarbon cynene (dipentene). At the same time Wallach showed that cajeputol[37] is identical with cineol, also cajeputene with cynene. The limonene odor of cinene (dipentene) lead Wallach to surmise the relations existing between this hydrocarbon and hesperidene (+limonene). The preparation of limonene tetrabromide[38] melting at 104° proved these suppositions to be true.

The importance of these tetrabromides soon became apparent. Already in his second contribution Wallach showed conclusively by means of the tetrabromide reaction that dipentene was formed in a large number of reactions. Wallach, at that time, characterized dipentene as follows: "It boils at 180–182°[39]. The odor resembles that of limonene. It combines with bromine to form a tetrabromide which crystallizes in the rhombic system and melts at 125–126°, also with two molecules of hydrogen chloride, without being changed thereby, to dipentene dihydrochloride which melts at 49°. At high temperatures it polymerizes without being previously modified."[40]

Dipentene is classified here as the special hydrocarbon of the dipentene group, whereas the closely related "hesperiden" (+ limonene) is placed in the limonene group.[40] The reason for such a separation is quite apparent. The inactive modifications of pinene and camphene are not essentially different from their optically active modifications. Lævogyrate limonene was not yet known as such. It was only with the discovery of this terpene on the part of Wallach[41] that the true relations existing between dipentene and the optically active limonenes could become wholly apparant. Whereas the relations existing between o-pinene and ± pinene are those of o-tartaric and to ± tartaric acids, the relations existing between o-dipentine and ± limonene are explained by those existing between o-racemic acid and the optically active tartaric acids.

Dipentene, therefore, is not optically inactive limonene in the same sense in which o-pinene and o-camphene are the optically inactive modifications of the respective groups. That dipentene derivatives, prepared synthetically from the optically active modifications, have but a simple molecule has been shown by Wallach in connection with optically inactive carvoxime.[43] On account of the peculiar position of the optically inactive members of derivatives from the limonene group he has retained the designation "*dipentene*" in preference to *0–limonene*, for optically inactive limonene derivatives corresponding to those of optically inactive tartaric acid may yet be found.

Properties.

The hydrocarbons of the limonene group are colorless liquid terpenes of an agreeable lemon-like odor.[1] Two of the three are optically active, being opposite in character. The physical constants of the limonenes have been determined as follows:

Boiling point, 175—176°.[2][3]
Spec. gravity at 20° 0,846.[3]
$[\alpha]_D = 105°$[3] resp. $+ 106.8°$[2]
Coefficient of refraction n_D 1.47459.[3]
Molelecular refraction $\frac{(n^2-1)p}{(n^2+2)d}$ 45.23.[3]

Chemically the two modifications are identical. They add one molecule of hydrogen chloride without losing their optical activity. When every trace of moisture is avoided they will not add more.[4] In the presence of moisture, however, they add two molecules of hydrogen chloride and thereby become optically inactive, i. e., are converted into a dipentene derivative, dipentene dihydrochloride. The dibromine addition products appear to be viscid liquids and are therefore not characteristic. When hydrobromic acid is split off cymol results.[13] The tetrabromides, however, are very characteristic.[5] Optically[6] as well as crystalographically[7] their character is opposite. The limonenes add also nitrosyl chloride, apparently but one molecule. However, two addition products of $\left\{\begin{matrix}NO\\Cl\end{matrix}\right.$ result, an α—and a β—nitroso-chloride. With bases both yield the same α—and β—nitrolamines. Like limonene the monhydrochloride is still capable of adding the groups $\left\{\begin{matrix}NO\\Cl\end{matrix}\right.$ and $\left\{\begin{matrix}NO\\O\,(NO)_2\end{matrix}\right.$.

In this case, however, but one hydrochlor-nitroso chloride or hydochlor-nitrosate resp. results. The molecule of hydrogenchloride can also be added after the addition of the NO Cl group, viz., by the nitrolamines. Thus e.g. the α-nitrolanilid will yield an α-hydrochlor addition product, the β-nitrol anilid a β-hydrochlor addition product. Of these the α-base is identical with the one obtained from the hydrochlor-nitrosochloride.[8] These peculiarities, which have thus far been observed in connection with limonene group only indicate a different behavior of the two double bonds toward regents.

The behavior of the limonenes toward water is similar to that toward the hydrohalogens. After the addition of one molecule of water the hydration product still appears to be a limonene-derivative.[9]

The addition of a second molecule of water makes it a dipentene derivative. Terpin and its hydrate are both optically inactive and upon dehydration yield dipentene but no limonene.

The transformation of limonene to dipentene is termed *inversion* and seems to be brought about easily by the presence of acids. Thus e. g. a partial inversion takes place in the preparation of the nitrosochlorides and nitrosates, and especially of the hydrochlor nitrosochlorides and nitrosates[10]. Limonene can also be inverted into terpinene whereby dipentene results as intermediate product[11]. Indirect inversion into terpinolene[12] also seems to take place under favorable conditions. If the isoterpenes of Flawitzky[9] are but impure limonenes then the pinenes can be inverted into limonene by means of alcoholic sulphuric acid. It thus becomes apparent that limonene though a relatively stable terpene is by no means the most stable.

Dipentene closely resembles the limonenes in most of its properties Boiling poing 178°, spec. gravity 0.845 at 20°, $n_c = 1.47308$. It is readily distinguished from the limonenes by being optically inactive. Whether dipentene is physically identical with optically inactive limonene, resulting from a mixture of equal parts of dextro-and lævogyrate-limolimonene has not yet been decided. Chemically they are identical. Since in all characteristic cases the optically inactive limonene derivatives have been shown to be identical with the corresponding derivatives obtained from dipentene the term dipentene only will be used hereafter. The dihydrochloride is identical with the one resulting from the addition of two molecules of hydrogen chloride to the limonenes. The tetrabromide, however, is distinguished from the limonene tetrabromides in form, melting point and solubility. What has been mentioned of the limonenes with reference to nitrosylchloride also holds true for dipentene. It might yet be stated that all dipentene derivatives can also be obtained by mixing solutions of equal parts of the corresponding detro- and lævogyrate limonene derivatives. It is to be supposed that dipentene like limonene will add water to form terpin hydrate, but this has not yet been demonstrated.

Limonene as well as pinene and phellandrene can be inverted into dipentene, which in turn can be inverted into terpinene only. Dipentene is therefore one of the most stable terpenes.

OCCURRENCE.

Dextrogyrate Limonene:

In the oil of Citrus Limonum.[16]
“ aurantium.[17]
“ medica.[18] } [15]
“ bigaradia sienensis.[19]
“ “ myrtifolia.[19]
“ Bergamia.[20]
Carum Carvi.[21]
Anethum graveleus (Dill oil).[22]
Erigeron Canadense.[23]

Lœvogyrate Limonene:

In the oil of Laurus camphora (camphor oil).[24]
Pinus sylvestris. } (“Fichtennadel oel”).[25]
Pinus picea.

Dipentene:

In Camphor oil.[29]
“ Cubeb oil.[30]
“ Elemi oil.[31]
“ Olebanum oil.[32]
“ Swedish turpentine oil (modified natural product).[33]
“ Russian turpentine oil[34] (modified natural product).
“ Oil from leaves of Citrus Limetta.[35]
“ Oil of black pepper.[36]

The statements that Ol. Cinae, Ol. cajeputi and Ol. Eucalypti contain dipentene as natural product, are without proof.[37]

The presence of *limonene* can readily be ascertained in the fractions of volatile oils boiling about 175° by Tilden's nitrosylchloride reaction as modified by Wallach.[26] If the yield is not too small the α-nitrosochloride can be recrystallized from ether and recognized by its crystalline form.[27] The conversion of the crude nitrosochloride into carvoxime is characteristic but not easily performed. The double decomposition of the crude nitrosochloride with benzylamine is much simpler.[28] The α-nitrol-benzylamine base crystallizes in dull needles which melt at 93°. The tetrabromide reaction is also very characteristic but not as easily and readily performed as the one mentioned last.

Dipentene is found in fractions boiling from 175–180° It is characterized by means of its tetrabromide[38] melting at 124°, by means of its nitrosochloride and the benzylamine base obtained therefrom.[39] The α-base crystallizes well from dilute alcohol in colorless transparent crystals, melting at 109–110°.

Methods of Formation.

If the "Isoterpenes" of Flawitzky [9] are impure limonenes, then the latter can be obtained by inversion of the optically active pinenes through the optically active terpineols (terpene hydrates of Flawitzky).

Dipentene being more stable than its optically active modifications results from a large number of reactions:

I. Polymerisation of Isoprene, a hemiterpene. [40]

II. Inversion of less stable terpenes, viz.:

1. By means of heat: direct inversion into dipentene.
2. By means of acids—
    - a. Hydrohologen acids: into dipentene dihydrochloride, etc.
    - b. Sulphuric acid: apparent direct inversion.
3. By means of water in presence of acids (e. g. nitric acid) conversion into terpin hydrate.

According to these methods pinene, [41] limonene [42] and phellandrene [43] can be converted into dipentene.

III. Destructive distillation of polymerized terpenes: e. g. Kaoutchouc (Himly's "Kautschin").

IV. Regeneration of dipentene from derivatives:

1. Removal of hydrohalogen from dipentene dihydrochloride and dihydrobromide by means of alcoholic potash,[44] sodium acetate [45] or anilin.[46]
2. Dehydration of *0*–Terpineol or terpin, resp. terpinhydrate [47]

Methods of Preparation.

Dextrogyrate limonene is obtained by fractional distillation. Oil of sweet orange consists almost entirely of + limonene. The "carvene" of commerce and Erigeron oil are also very rich in + limonene and relatively cheap.

Levogyrate limonene is thus far obtained from "Fichtennadel öl" only.

Dipentene is best obtained by decomposition of its dihydrochloride or bromide by boiling with anilin.[46] The use of sodium acetate and glacial acetic acid[45] cause the formation of byproducts. It is rather difficult to remove the last traces of halogen.[5]

HYDROHALOGEN ADDITION PRODUCTS.

Monohydrochlorides.

History:

The question whether a limonene monhydrochloride analogous to pinene-monhydrochloride can exist has long remained an open one. Considerable speculation has been indulged in concerning the liquid byproducts, resulting in the preparation of dipentene-dihydrochloride. Some regarded it as a monhydrochloride, others as an isomeric liquid dihydrochloride. Those who supported the latter view termed it "camphre-liquide de citron" in opposition to the "camphre solide de citron" (crystalized dipentene dihydrochloride). From this "camphre liquide de citron" Soubeiran and Capitain[1] went so far as to prepare the hypothetical hydrocarbon "citrylène": spec. gravity 0.88, boiling point 168°, vapor density 5.08, optically inactive. More than this, they created a group of liquid camphors, in distinction to the solid and artificial camphors.

Characteristic as well as interesting are Berthelot's[2] views (1882). He had succeeded in preparing dipentene-dihydrochloride from pinene. From this he concludes that the difference between pinene and limonene ("essence de citron") is not "essentielle." Consequently limonene *must* yield a mono hydrochloride, analogous to artificial camphor. However "sa préparation est difficile, car elle parait se produire seulement en faible proportion et *d'une manière accidentelle*."

That under such conditions it is perfectly impossible to interpret all older statements in the light of present knowledge is certainly apparent. A complete catalogue of all the literature that has reference to this particular subject would therefore be useless. In most cases it may be assumed that these liquid products were mixtures of mono- and dihydrochlorides.

A statement by S. de Luca[3] (1887) appears to be more rational. When he passed dry hydrogen chloride into relatively pure limonene from the citrus bigaradia *no solid compounds would result.* Crystallized dipentene-dihydrochloride, however, resulted when the oil was shaken with aqueous hydrochloric acid. de Luca, however, makes no statements regarding composition and character of this liquid chloride. Ribans[4] statements (1874) are more important. By passing dry hydrogen chloride into limonene a liquid monhydrochloride resulted which could be converted into crystallizable dihydrochloride by treatment with moist hydrogen chloride. Bouchardat[5] (1875) claims to have obtained a liquid monhydrochloride and a solid dihydrochloride. Maissen[6] (1883) also obtained a hydrohalogen addition-product which was *not* saturated. From these statements by de Luca, Berthelot and Maissen it would seem that the hydrogen chloride must be dry to yield a monhydrochloride. Others[7], however, who according to their statements employed dry hydrogen chloride obtained dipentene-dihydrochloride and no monhydrochloride. It is therefore not at all surprising that Wallach[8] (1887) after an unsuccessful attempt to prepare a monhydrochloride denied the existence of such a compound. The study of Maissens compound (dipentene-hydrochlor-nitrosate), however, again brought up this question.

As a result of these investigations it became apparent that a monohydrochloride of limonene could exist, and that it was an *unsaturated* compound. The understanding of Riban's and Maissan's experiments had to make the latter fact apparent, but Wallach first called attention to it. Physical as well as chemical characteristics were first studied by him. Wallach's monohydrochloride was, as I have shown, chiefly dipentene-monhydrochloride.[10] The optically active monhydrochlorides were first described by me.[11]

Properties.

Since there is no criterion to ascertain the purity of the monhydrochlorides the following data found for the three physical isomers will have to be accepted at present:[11]

+ *Limonene-monhydrochloride.*

"A colorless, mobile liquid of faint limonene odor. It boils at 97–98° under pressure of 11–12 mm. Spec. gravity 0.973 at 17.8°; $[\alpha]_D = +39.5°$."

—*Limonene-monhydrochloride.*

"This corresponds with the dextrogyrate compound in all but its optical properties. The rectified product boiled at 95–96° under a pressure of about 11–12 mm.; spec. grav. 0.982 at 16°; $[\alpha]_D = +40.0°$."

Dipentene-monhydrochloride.

It was prepared by mixing equal parts of the above dextrogyrate and lævogyrate compounds. "The mixture was optically inactive; spec. gravity 0.982 at 16.5°; boiling point 98° under pressure of 12 mm." Wallach[12] ascertained the physical properties of a *dipentene* compound to be as follows: Boiling point 90° under pressure of 11 mm.; spec. grav. 0.98; $n_C = 1.4789$, molecular refraction 49,86, calculated for an unsaturated compound $C_{10}H_{17}Cl$ 50,28.

Chemically the monhydrochloride behaves like an unsaturated compound. Under the conditions, however, which are most favorable to its formation it will not add a second molecule of hydrogen chloride.[11] But in the presence of moisture it adds another molecule and the limonene derivative is thereby converted into a dipentene derivative. It also adds $\left\{\begin{matrix}H\\Br\end{matrix}\right.$[13] $\left\{\begin{matrix}NO\\Cl\end{matrix}\right.$[14] and $\left\{\begin{matrix}NO\\O\,(NO_2).\end{matrix}\right.$[15] Chlorine very likely also can be added, but this apparently substitutes at the same time.[16] Water is not added directly. In the presence of water the chlorine is substituted by hydroxyl,[16] and the aqueous hydrochloric acid acts upon the terpineol to form terpin hydrate.[17]

The monhydrochlorides polymerize in a very peculiar manner.[18] Hydrogen chloride is split off at the same time and partial inactivity results when the underlying hydrocarbon was optically active.

The hydrogen chloride is not easily removed and traces of chloride are apt to remain. The regenerated hydrocarbon is a mixture of limonene and dipentene[19].

Preparation.

When *dry* hydrogen chloride is passed into a *dry* solution of limonene or dipentene in carbon disulphide the monhydrochloride alone results. For technical details compare the original.[20] Dipentene monhydrochloride can also be prepared by splitting off a molecule of hydrogen chloride from dipentene dihydrochloride[21].

Identification.

The monhydrochlorides can easily be identified by means of the hydrochlornitrolaminebases. The preparation and purification of the hydrochlornitrolbenzylaminebase is easily carried out[22].

Dipentene-dihydrochloride.

Synonyms.

Muriate Citré — Th. de Saussure, 1820.
Camphre de Citron — J. Dumas, [2] 1833.
Citrêne chlorhydrate — J. Dumas, [2] 1833.
Festes salzsaures Citronenoel — Blanchet & Sell, [4] 1833.
Salzsaures Kautschin — Himly, [5] 1835.
Hydrochlorate de Citrène — Laurent, [6] 1837.
Camphre solide [7] de citron — Soubeiran and Capitain. [8] 1840.
Chlorwasserstoffsaures Carven — Schweizer, [9] 1840.
Chlorwasserstoff Terpin — List [10] 1848.
Bichlorhydrate d'essence de Térébenthine — Berthelot, [11] 1852.
Dichlorhydrate de terpilène — Berthelot, [12] 1861.
Zweifach chlorwasserstoffsaures Terpilen — Oppenheim, [14] 1864.
Dihydrochloride of citrene — Yoshida, [15] 1885.
Cynen dihydrochlorid — Hell & Ritter, [16] 1884.
Dipenten-Dihydrochlorhydrat — Wallach, [17] 1884.
Chlorhydrate de terpelène — Bouchardat & Lafont, [18] 1886.
Dipenten-Dihydrochlorid — Wallach [17] 1887.

History:

Dipentene dihydrochloride is one of the oldest characteristic terpene derivatives. The so-called artificial camphor, the pinene monhydrochloride alone has claim to priority.[19] In an article "Sur la combinaison des acides avec les substances végétales et animales." Thenard in 1807 mentions a crystalline substance which resulted upon the absorption of hydrogen chloride by lemon oil. There can scarcely be any doubt as to the identity of this substance. At least Blanchet and Sell[4] mention Thenard as the discoverer of the compound under consideration. The fact that Thenard recognized that the hydrochloric acid was *added* without causing a decomposition of the molecule adds to the interest of the discovery.

In 1820 Saussure[1] prepared dipentene dihydrochloride in pure form and described the same. He calls attention to the physical differences between this "muriate citré" and the "muriate térébinthiné." From it he also regenerated the hydrocorbon.

J. Dumas,[2] in 1833, accepts the formula $C_5 H_4 + \frac{1}{2} H \frac{1}{2} Ch$ for the "camphre de citron."

In the same year Blanchet and Sell[4] characterize the "salzsaure Citronenöl" as follows: "From ether it crystallizes in laminae with a silver lustre and of tuberose-like odor. It melts at 43° and sublimates at 50° without decomposition," etc. Percentage of chlorine 33.5 p. c.; formula $C_5 H_8 + Cl H$. Thenard has tried to ascertain the composition of the compound by noting the quantity of hydrogen chloride absorbed by the oil. Saussure destroyed the substance with nitric acid and precipitated the chlorine as silver chloride. He obtained 27.6 p. c. chlorine. Blanchet and Sell employed the lime method. These chemists also supposed that by the action of hydrogen chloride upon lemon oil two solid compounds are formed, the one of which decomposes into hydrochloric acid and oil when recrystallized from warm alcohol, the other being more stable. The latter is termed "salzsaures citronyl" (the substance under consideration), the other "salzsaures Citryl."

Himley[21] (1835) obtained "Salzsaures Kautschin" by passing hydrogen chloride into "Kautschin" (dipentene) and regenerated the hydrocarbon by distillation with lime and rectification over potassium.

Soubeiran and Captain[8] (1840) mention the readiness with which dipentene dihydrochloride decomposes: "Il suffit même d'évaporer une dissolution alcoolique de ce camphre pour qu'il soit détruit en partie," etc. They do not accept Blanchet and Sell's view regarding the mixture of two isomers. They recognize the fact that the "camphre de citron" and also the regenerated "citrene" are optically inactive.

Schweizer[9] (1840) assigns to his "chlorwasserstoffsaures Carven," the formula $C_{10} H_{16} + Cl_2 H_2$. He regards it as *isomeric* with the solid compound obtained by the action of hydrogen chloride upon lemon oil, copaiva oil, and orange oil, with which it corresponds more or less in some of its properties.

List[10] (1848) regards the chlorhydrate "$C_{20}H_{1\infty}Cl_2$" obtained from the terpin as *isomeric* with the one obtained by Blanchet and Sell and by Dumas. He claims cyrstallographic differences, also differences in melting points and solubility.

Deville's observation of 1849 is of some interest: "Les hydrates de térébenthine donnent avec l'acide chlorhydrique de l'eau et du camphre de citron dont on peut retirer une huile qui par ût identique avec l'essence de citron elle-même, ce qui fournit le moyen de transformer l'essence de térébentine en essence de citron."

Berthelot [11] obtained (1852) dipentene dihydrochloride directly from turpentine oil by shaking the latter with aqueous hydrochloric acid, or by passing hydrogen chloride into a solution of turpentine oil in ether, alcohol or glacial acetic acid.

Trying to replace the three molecules of "water radicles" in terpin hychlorine, Oppenheim [14] (1862) always obtained the dihydrochloride of dipentene.

These extracts and remarks may afford sufficient insight into the older literature of the dihydrochloride of dipentene. To give complete literary references up to date would be useless. From the above it becomes obvious that with a better knowledge of this compound some light was shed over the relations of terpenes in general. It must also be obvious, however, that for many it was a stumbling block and brought about greater confusion. Some chemists indeed recognized the identity of this compound from whatever source they obtained it, others denied the same. In the imaginations of some there were as many dihydrochlorides as there were terpenes, and these were limited only by the number of volatile oils containing hydrocarbons of the formula $C_{10}H_{16}$.

In spite of Berthelot's ideas Gladstone's [24] (1864) classification of the terpenes gained ground more and more. According to this dipentene dihydrochloride was regarded as the characteristic addition product of "citrene" (+ limonene) and allied terpenes, whereas artificial camphor was taken as characteristic derivative of the "terpenes" (pinene and allied terpenes.)

In the following twenty years little was added to a better understanding of this compound. A full understanding was possible only after the discovery of lævogyrate limonene, (1888) i. e., after the completion of the limonene group and synthesis of dipentene derivatives.

Properties.

Dipentene dihyrochloride crystallizes in pearly laminæ which melt at 50°.[25] It is insoluble in water, soluble in alcohol and ether, readily soluble in chloroform, from which solution it can be precipitated with methyl alcohol. Its presence effects a decrease of the melting-point of other substances.[22]

Chemically, dipentene dihydrochloride behaves like a saturated compound, and as a terpene derivative it is relatively stable. By splitting off one or both hydrogen chloride molecules it is converted back into unsaturated compounds. Heated by itself,[28] or in alcoholic solution.[29] it decomposes into its components, dipentene and hydrogen chloride. Caustic potassa and anilin split of hydrogen chloride, but the last traces of chlorine are very difficult to remove.[30] Solution of permanganate of potassium attacks it readily.[31]

Methods of formation:

I. Addition of hydrogen chloride:
   1. To the monhydrochlorides of the limonene group.[32]
   2 To the hydrocarbons of this group.[33]

The optically active hydrocarbons are hereby inactivated. The indirect formation from cineol[34] is to be classed with 2, since the hydrogen chloride acts first as a dehydrating agent forming "cinene" (dipentene).

II. Esterification of the diatomic alcohol terpin and its hydrate:
   1. By means of hydrochloric acid.[35]
   2. By means of the tri- and pentachlorides of phosphorus.[36]

Ad I and II. The formation from the terpineols[37] no doubt consists in an esterification of the monatomic alcohol and subsequent addition of a second molecule of hydrogen chloride.

III. Inversion and addition:
   e. g. From pinene,[38] phellandrene,[39] and probably from terpinolene.[40]

Preparation.

Larger quantities of dipentene dihydrochloride are rationally prepared by passing hydrogenchloride over (not into) a solution of limonene in one-half its volume of glacial acetic acid. A rise in temperature of the solution must be avoided to prevent the formation of oily products. After the solution has congealed to a crystalline mass it is poured into water and the drained chloride is purified by dissolving it in alcohol and precipitating with water.[41]

Small quantities can be readily purified by dissolving in chloroform and precipitating the solution with methyl alcohol.

Dipentene-Dihydrobromide.

Dibromhydrate de terpiline, Berthelot,[42] 1861.
Zweifach bromwasserstoffsaures terpilen, Oppenheim,[14] 1864.
Cynen-dihydrobromid, Hell and Ritter,[16] 1884.
Dipenten-dihydrobromid, Wallach,[17] 1887.

History.

Dipentene-dihydrobromide was first prepared by Berthelot[42] from terpinhydrate analogous to the chloride. In the following year (1862) Oppenheim[14] prepared it from terpinhydrate with tri- and penta bromide of phosphorus. In 1884 Hell and Ritter[16] prepared it from cineol analogous to the chloride. Wallach has repeatedly prepared the dihydrobromide from dextrogyrate limonene, dipentene, terpinhydrate,[43] also from terpinolene.[44]

Properties.

In its properties the bromide resembles the chloride. Melting point 64°. (Hell & Ritter[16] 42°.)

Methods of Formation.

These are analogous to those of the chloride. In how far they have been carried out can be seen from the historical sketch.

Preparation.

Dipentene dihydrobromide can be prepared in few minutes when to a solution of limonene or dipentene an excess of a saturated solution of hydrobromic acid is added. The mixture must be left cold, and when poured into water the dihydrobromide is precipitated in pure condition.[45].

Dipentene Dihydriodide.

Zweifach jodwasserstoffsaures Terpilen — Oppenheim.[14] 1862.
Cynen-Dihydrojodid — Hell und Ritter.[16] 1884.
Dipenten-Dihydrojodid — Wallach.[17] 1887.

History.

Wiggers[46] and also List[10] did not succeed in preparing a hydriodide analogous to the hydrochloride. Oppenheim was the first to succeed. He obtained it by treating terpin hydrate with phosphorus iodide. The product, however, cannot have been pure as indicated by the melting point 48°. Hell & Ritter[16] (1884) obtained the hydriodide analogous to the hydrochloride and hydromide from cineol. Melting point 76–77°. At the same time and independently Wallach and Brass[47] obtained the same compound from the same material. Wallach also prepared it from terpin-hydrate[48] and terpineol[49] with the aid of hydriodic acid.

Properties.

In its properties the dihydriodide is analogous to the dihydrochloride and dihydrobromide, but it is less stable. However with its purity its stability increases. From petroleum ether it crystallizes in two physically isomorphous modifications[50]: rhombic crystals melting at 77° and monosymmetric crystals melting at 78–79°.

Methods of Formation:

These are analogous to those above mentioned. In how far they have been carried out can readily be seen from the historical notes.

Preparation:

1. Analogous to that of the hydrobromide.
2. From terpin hydrate: to 5 g. terpin hydrate contained in a flask about 20 cbcm. of conc. hydriodic acid (spec. grav. 1.96) are added and the mixture is shaken without the application of heat. The transformation into the iodide takes place quantitavely. The drained product is crystallized from petroleumether in which terpin hydrate is almost insoluble.[51]

THE HYDRATES OF THE LIMONENE GROUP.

Terpin and Terpin-hydrate.

Synonyms.

Pyrocamphorium[1] — Trautwein.
Terpenthin salz[1] — Buchner,[2] 1820.
Terpentinölcamphorid[1] — Trommsdorf,[3] 1828.
Terpin[1] — Berzelius,[4] List,[5]&[9] 1848.
Trihydrate d'essence de térébenthine[1] — Deville.
Turpentine camphor[1] (C^{20} C^{20} O^4).
Hydrate of oil of turpentine.[1]
*Terpenthincampher — Blanchet and Sell,[6] 1833.
*Wachholderbeerenölhydrat } Blanchet and Sell,[7] 1833.
*Terpenthinhydrat }
Terpenthincampher — Wiggers,[8] 1840.
Terpentinölhydrat,[9] 1884.
Hydrate de térébenthine } Deville,[10] 1849.
Bihydrate d'essence de térébenthine }
Terpinhydrat — Wallach.[11]

History.

Disregarding the dehydration products the chemical literature of terpin, resp. of terpin hydrate at first sight appears to be very simple. According to Gmelin[1] terpin hydrate was observed as early as 1827, by Geoffroy; Buchner[2] is stated to have regarded it as a salt of succinic acid with a volatile base, whereas Dumas and Peligot[12] and then Wiggers[8] considered it to be a hydrate of turpentine oil. It is rather strange that Blanchet and Sell[7] are not mentioned by Gmelin in his historical review. The same views, however, have been expressed before, viz.: by Blanchet and Sell,[13] by the publishers of the "Annalen der Chemie und Pharmacie," and by List. They are the same we find in our

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* Those marked with *, no doubt, pertain not to terpin or its hydrate but to pinol hydrate which was not recognized as such at the time.

hand-books to-day. A critical study, however, must throw doubt upon at least some of their statements. Unfortunately time does not permit at present to verify these doubts by experimental evidence. Nevertheless, the same, as well as the reasons therefore, shall be mentioned. If Blanchet and Sell's contribution[13] be read in the light of our present knowledge of terpin hydrate several points will have to be regarded in a rather doubtful light. The same is true of the historical sketch given by the editors of the "Annalen." It is even stranger that List could make the remark that the older analytical results correspond, whereas they fall very distinctly into two categories. An explanation for their views is probably to be found in the fact that at an early date terpin hydrate was converted into terpin free from water of crystallization, and that pinol hydrate, a substance approaching terpin closely in empirical composition had not been recognized as such. To make physical differences agree or to regard such differing statements as misprints may be admitted a single time, a repetition of such a procedure, however, must create suspicion. An attempt to bring all statements concerning the so-called "terpentine oil hydrate" in harmony with actual facts would leave a number of points unexplained. This riddle, however, may be solved by substituting pinol hydrate in place of terpin (free from water of crystallization) whenever necessary. The following table may, therefore; serve as a key to a better understanding of the terpin-literature.

$C_{10}H_{20}O_8$	$C_{10}H_{18}O_2$		Blanchet & Sell.	Dumas & Peligot.			Sten-house.		Wiggers.		Sobrero.
69.76	70.58	C	70.91	....	....	....	69.99	70.30	......	.....	70.58
11.62	10.58	H	11.05	....	....	....	11.68	11.62	......	.....	10.58
$C_{10}H_{22}O_3$	63.15	C	....	*a.* 63.8	*b.* 63.8	*c.* 64.0	.....	.....	63.315	63.25	.....
	11.57	H	....	11.4	11.5	11.4	.....	.....	11.555	11.56	.....
Melting point....		....	150°	....	....	....	150°		......	.....	*

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* Armstrong has shown recently that pinol hydrate prepared according to Sobrero melts at 150° (J. C. S, June, 1891, J. 317.)

Properties.

Terpin hydrate crystallizes in large transparent prisms.[17] It is soluble in 250 p. of water, 10 p. alcohol, 100 p. ether, 200 p. chloroform; in 32 p. of boiling water and 2 p. of hot alcohol;[18] it is insoluble in petroleum ether. It melts at 116–117°, sublimating at the same time. When heated in a flask the water of crystallization is first given off with which a portion of the substance passes over, then the anhydrous terpin distills at 258°. The anhydrous terpin congeals to a hard crystalline mass which melts at 102–105°.[20]

Terpin and its hydrate are saturated compounds [19] when boiled with acids or other dehydrating agents there results first of all the monatomic unsaturated alcohol tepineol, $C_{10} H_{18}$. Further dehydration yields according to the conditions and dehydrating agent employed, three hydrocarbons $C_{10} H_{16}$ differing essentially in their properties: terpinene, terpinolene and dipentene.[21] Cineol also results, but only in small quantities[22] When treated with the hydrohalogen acids dipentene dihydrochloride,[23] dihydrobromide [24] and dihydriodide [25] result respectively. When treated with the chlorine, bromineand iodine derivatives of phosphorous the same dipentene derivatives result.[26] Hydrofluoric acids also acts upon terpin hydrate but the resulting products have not been studied[27]. With nitric acid it appears to yield an ether from which upon saponification the alchol can be regenerated only in part.[28] Nitric acid[29] also oxidizes terpin hydrate; permanganate solution[30] even more readily.

Occurrence.

In some text-books it has been stated that terpin hydrate has been found in the oil from Acimum basilicum, L., and in Cardamom oil. This however, is not at all to be considered as a natural occurrence. To our knowledge terpin hydrate does not occur in plant organs.

Determination.

Characteristic for terpin hydrate are its crystalline form and its melting point, as also the melting-point of the anhydrous terpin. Chemically it can be characterized by converting it into any one of the dipentene-hydrohalogen derivatives. Of these the di-hydriodide can be prepared most readily.[31]

Methods of Formation.

Hydration of—

1. The hydrocarbons $C_{10} H_{16}$:
    - (a) Limonene.[32]
    - (b) Pinene [33] (whereby inversion takes place.)

II. The alcohol terpineol [34] $C_{10} H_{18} O$. As an indirect formation that from limonene monhydrochloride [35] may be considered under terpineol.

Preparation.[36]

According to Hempel, who compared the methods of Wiggers and Deville, 8p. of turpentine oil are mixed with 2p. nitric acid (spec. gravity 1.25—1.3) and 2p. alcohol. The mixture is shaken several times daily until crystals begin to form. To obtain crystals in comparatively short time shallow dishes can be employed. The drained crystals are re-crystallized form alcohol.

Terpineol.

Synonyms:

Terpineol[1] — List[2] 1848.
Berthelot[3] 1852.
Oppenheim[4] 1864.
Tilden[5] 1878.
Tanret[6] 1885.
Diterebenhydrat — Oppenheim[4] 1864.
Terpinhydrat — Flawitzky[7] 1879 and 1887.
Monohydrate de Térébenthène — Tanret[6] 1885.
Terpineol — Wallach[8] 1885.
Terpilenol } Bouchardat and Voiry[9] 1887.
Terpol }

History:

In an impure form, as so-called "terpinol," terpineol has given rise to manifold speculations, which need not be considered here. Both Tilden[5] and Flawitzky,[7] according to opposite methods, obtained relatively pure terpineol, but it was Wallach who first introduced order into the chaos of older speculations. By means of a systematic study of the dehydration products of terpin, in which all side reactions were avoided as much as possible he ascertained that terpineol is the first dehydration product of terpin, and that by further dehydration it is converted, according to conditions, and reagents into one or more of three hydrocarbons, viz., dipentene, terpinene, terpinolene; also that in the process of dehydration of terpin small quantities of cineol are formed as byproduct. These few introductory remarks will enable us to interpret the older literature upon this subject.

In 1846 Wiggers[10] obtained from terpin hydrate by heating the same with hydriodic acid a compound to which he assigns the formula $C^{20} H^{16} + \dot{H}$. The results of his analyses do not at all agree well with this formula. He remarks that this substance might be regarded as the "Oxyd von einem aus dem Terpentinöl neuentstandenen Radical = $C^{20} H,^{17}$ wozu, aber, wie es scheint durchaus kein Grund vorhanden ist."

In 1848 List[2] supposes to have obtained the same substance Wiggers had in hands by boiling terpin with acidulated water (one drop of conc. sulphuric acid sufficed to decompose 11.5g terpin). The substance termed "Terpinol" by him is stated to possess a hyacinth-like odor, especially when largely diluted and to boil *constantly* at 180°. When saturated with hydrogen chloride it yields the same chloride as does terpin hydrate. (Dipentene dihydrochloride.) This fact, List supposes, supports Berzelius' view (27, Jahresbericht, p. 445,) that terpinol is the oxide of a radical $C^{20}\,H,^{17}$ and that terpin is the hydrate of terpinol. The following formulæ are to express "die verschiedenen Betrachtsungsweisen der Constitution dieser Körper:"

Crystallized Terpin: —

$$C^{20}\,H^{22}\,O^{6} = C^{20}\,H^{16} + 6\dot{H} = C^{20}\,H^{17}\,O + 3\,\dot{H} + 2aq.$$

Anhydrous Terpin: —

$$C^{20}\,H^{20}\,O^{4} = C^{20}\,H^{16} + 4\dot{H} = C^{20}\,H^{17}\,O + 3\dot{H}.$$

Terpinol: —

$$C^{20}\,H^{17}\,O = C^{20}\,H^{16} + \dot{H} = C^{20}\,H^{17}\,O.$$

"Chlorwasserstoff Terpin": —

$$C^{20}\,H^{18}\,Cl^{2} = C^{20}\,H^{16} + 2H\,Cl = C^{20}\,H^{17}\,Cl + H\,Cl.$$

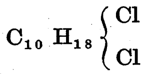
However, these views do not satisfy List, for "es erheben sich dagegen alle die Umstäde, welche gegen die Annahme sprechen, das der Alchohol das Hydrat der Aethers und dieser das basische Oxyd von $C^{4}\,H^{5}$ sey."

According to Oppenheim[4] (p. 155) Berthelot[3] (1852) is stated to have obtained "terpinol" "bei der Einwirkung von Kali auf die zweifach chlorwasserstoffsaure Verbindung des Terpilens." He accepts the formula "$C_{20}\,H_{16}$, HO."

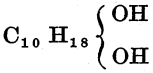
Oppenheim[4] (1864) claims to have obtained "das Terpinol von Wiggers und List" by treating "zweifachbromwasserstoffsaures Terpilen" with acetate of silver: $2C_{10}H_{18}Br_{2} + 4C_{2}H_{3}\,AgO_{2} = 4Ag\,Br + \left.\begin{matrix}C_{2}\,H_{3}\,O\\C_{2}\,H_{3}\,O\end{matrix}\right\}O + 2C_{2}\,H_{4}\,O_{2} + C_{20}\,H_{34}\,O$. This "terpinol" boiled between 165–208°. Oppenheim acknowledges that *he could never obtain a product of constant boiling point;* also that Gerhardt doubted the existence of such a substance. As an "Aether des Terpins" Oppenheim designates a substance which very likely was impure acetate of terpineol. (p. 157.)

By boiling terpinhydrate with water acidulated with hydrochloric acid Tilden[5] (1878) obtained a substance $C_{10}\,H_{18}\,O$, resp. $C_{10}\,H_{16}.\,H_{2}\,O$ to which he assigns the double formula $C_{10}\,H_{18} < \begin{matrix}O\\O\end{matrix} > C_{10}\,H_{18}$. He retains for it the term terpinol and supposes it to be an ether or anhydride of terpin, i. e. to stand in the same relation to terpin as ether does to alcohol. "Almost conclusive evidence of this is supplied by the action of hydrochloric acid, which does not give a monochloride as might be expected if terpinol had the constitution expressed by $C_{10} H_{17}$ (O H)."

In the following year, however, a vapor density determination compels Tilden to accept the simple formula $C_{10} H_{18} O$. "It is somewhat remarkable that this chloride (i. e. dipentene dihydrochloride) thus formed from terpinol, corresponds in constitution not with that substance but with terpin.



$$C_{10} H_{18} \begin{cases} Cl \\ Cl \end{cases}$$



$$C_{10} H_{18} \begin{cases} OH \\ OH \end{cases}$$

although when decomposed by alkalis it yields terpinol and not terpin."

Tanret[6] (1885) states that the formula $(C_{20} H_{16})_2 H_2 O_2$ for terpinol ought to be rejected, that terpinol proper boils between 215–220° and is a monohydrate of terebenthene $(C_{20} H_{16} H_2 O_2$; also that the product which results from the action of dilute acids upon the terpin, or of alcoholic potassa upon "Terebenthen dichlorhydrat" are but mixtures of a hydrocarbon $C_{20} H_{16}$ with monohydrate.

Since we shall have occasion to refer repeatedly to Wallach's[8] (1885) researches on terpineol it may suffice here to mention the results of his dehydration experiments, which, as has already been mentioned served as a key to a better understanding of this part of the limonene literature. Hydrochloric and nitric acids were not employed as dehydrating agents on account of the byproducts to which they give rise: hydrochloric acid to chlorides, nitric acid to oxidation products. The products resulting upon treatment of terpin hydrate with

sulphuric acid (1:2) are	terpinene. terpinolene. terpineol.
sulphuric acid (1:7)	terpinene (largely).
phosphoric acid [spec. gr. 1.12 = 20 p. c.] (1:4):	terpineol and terpinene or dipentene.
phosphoric acid [spec. gr. 1.12 = 20 p. c.] (1:2):	terpineol (exclusively).
glacial acetic acid	terpineol (essentially).
potassium bisulphate:	terpineol. dipentene.

Terpineol always results as intermediate product and upon further dehydration is converted into one or more of the above mentioned terpenes. "*Bei der Zerlegung des Terpinhydrats durch Säuren od. durch wasserentziehende Mittel ensteht unter keiner Bedingung eine Verbindung von der Zusammensetzung $C_{20} H_{34} O$ und dem Siedepunkt 168°.*

Thus far the terpineol under consideration, whether pure or impure as "terpinol," always showed itself to be optically inactive.

Bouchardat and Lafont[11] report (1886) on a series of experiments pertaining to the action of acids on the terpenes. The action of acetic acid on pinene furnishes a mixture of acetates which can be separated by means of fractional distillation under diminished pressure. The separated acetates yield upon treatment with alcoholic potassa optically active terpineol and borneol respectively. Whereas, by this treatment pinene could be converted into terpineol and borneol, camphene could be converted into borneol only, dipentene into optically inactive terpineol, dextrogyrate limonene[12] into dextrogyrate terpineol. From the o–terpineol they obtained crystals at a very low temperature.

With the introduction of new terms, viz.: "terpilenol" and "terpol" for terpineol, and of "terpal" for cineol Bouchardat and Voiry[9] (1887) have rendered poor service to science. Their disregard of the results achieved by others certainly is not honorable.

Flawitzky[7] $\left\{\begin{matrix}1879\\1887\end{matrix}\right\}$ prepared optically active monohydrates, which he termed "Terpenhydrate," by treating dextro — and lævogyrate pinene with alcoholic sulphuric acid. No doubt, these terpenehydrates as well as the "terpilenoles" of Bouchardat are optically active terpineols inactivated more or less by the presence of optically inactive terpineol. When dehydrated with acetic acid anhydride they yielded optically active hydrocarbons $C_{10}H_{16}$ which Flawitzky termed "Isoterpene" and which, to judge by their properties were more or less impure limonenes.

Properties.

Terpineol is a viscid[13] liquid[18] of agreable odor,[14] lighter than and insoluble in water, readily soluble in alcohol. It is volatile with water vapors and boils between 215–218° [15]. That obtained from dipentene and and terpin is optically inactive, [6] that obtained from optically active pinene and limonene is optically active.[17]

Terpineol is an unsaturated compound.[19] The addition of water converts it into terpin and its hydrate.[20] The removal of a molecule of water dehyrates it according to reagents and conditions to dipentene,[21] terpinene or terpinolene,[22] but never to pinene. The hydrohalologen acids convert terpineol like terpin into the dihydrohalogen addition products of dipentene i. e. the dihalogen esters of the diatomic alcohol but not into a monohalogen ester of the monatomic alcohol terpineol[23], probably according to the equation.[24]

$$C_{10}H_{17}OH + HCl = C_{10}H_{18}\left\{\begin{matrix}Cl\\OH\end{matrix}\right.$$

$$C_{10}H_{18}\left\{\begin{matrix}Cl\\OH\end{matrix}\right. + HCl = C_{10}H_{18}Cl_2 + H_2O.$$

The monohydrochlorides of the limonenes, no doubt are to be regarded as monochlorine esters of the terpineols.[25] Apparently the acetic ester can be prepared from the alcohol.[26] When saponinfied with alcoholic potassa thes esters yield the corresponding terpineols.[11–12] Presumably nitric and sulphuric acids are capable of forming similar compounds, which, however, are very unstable. The presence of water at a normal temperature suffices to sapoinfy them.[27] Phosphoric acid converts terpineol into the isomeric cineol.[28] With carbanil terpineol yields a crystallizable phenyl-terpinyl-urethane, which sufficiently demonstrates the alcoholic nature of the same.[29] Apparently the hydroxy hydrogen can be replaced by sodium.[30] Whereas very dilute nitric acid causes the formation of terpin hydrate more concentrated acid oxidizes. Potassium permanganate also readily oxidizes terpineol.[31]

Methods of Formation.

I Hydration of
    Pinene.
    Limonene and Dipentene.

II Dehydration of
    Terpin, resp. terpin hydrate.

III Saponification of
    1. The acetates of the terpineols.
    2. The dihalogen esters of terpin.

Preparation.

To prepare optically inactive terpineol 25 g. of terpin hydrate are boiled with 50 cbcm. of phosphoric acid, specific gravity 1.12 [= 20 per cent.] for 10 or 15 minutes, or 50 g. of terpin hydrate are boiled in a flask attached to a reflux condenser with 100 cbcm. glacial acetic acid for five or six hours. The resulting products are distilled with water vapor. The dried oil is rectified and the fraction boiling between 215–218° is collected[8]. The optically active terpineols can be obtained according to Flawitzky[7] by hydration of the pinenes by means of alcoholic sulphuric acid, or according to Bouchardat and Lafont[11]&[12] by saponification of the acetic esters (obtained from the optically active pinenes or limonenes) by means of alcoholic potassa.

Occurrence and Identification.

Thus far the analysis and boiling point of terpineol and the conversion into dipentene dihydrochloride have served as factors for its identification. Whether these data are sufficient is rather questionable. If possible the carbanil reaction should be employed. If the latter be taken as the only true criterion the presence of terpineol in natural products has not yet been absolutely proven. However, the occurrence of terpineol in a number of volatile oils is very probable.

Nitrosochlorides, Nitrosates, Nitrolamines.

History:

According to Wallach[2] Bunge was the first to prepare a nitrosyl chloride derivative of a terpene. Tilden,[3] however, was the first who examined it more carefully and described it. Thus he obtained from the class of "terpenes" (pinene) an optically inactive nitroso chloride which melted at 103°, and which, by splitting off hydrogen chloride was converted into the characteristic nitroso terpene, melting at 129°. From the class of "citrenes" (limonene) he obtained an isomeric, optically active nitroso chloride, which, by splitting off hydrogen chloride, was converted into a nitroso derivative ("nitroso herperidene") isomeric with "nitroso terpene," and whose melting point was 70–71°. These reactions henceforth characterized Gladstone's[4] "terpenes" and "citrenes," and the identity of herperidene, carvene and citrene could no longer be doubted. Tilden's method of preparing the nitroso chlorides by passing nitrosyl chloride into a solution of terpene, however, was very defective. Neither did Tilden surmise that his "herperidene nitrosyl chloride" was a mixture.

In 1885 Goldschmidt[5] showed that the oxime from carvol was chemically identical with "nitroso herperidene" of Tilden. Soon after (1888) Wallach[6] taught how to prepare the nitroso chlorides in large quantities with the aid of hydrochloric acid and amylnitrite, also the preparation of the nitrolamines. Fully as important was the discovery that the nitroso chlorides were mixtures and that they could be separated into the α and β compounds (1889).[7]

Preparation.

Wallach's method of preparation is as follows: "To 5 cbcm. of limonene, 7 cbcm. of amyl nitrite (or 11 cbcm. of ethyl nitrite) and 12 cbcm. of glacial acetic acid are added, and to this solution, kept cold in a freezing mixture, a solution of 6 cbcm. of crude muriatic acid in 6 cbcm. of glacial acetic acid is carefully added in small quantities. Finally 5 cbcm. of alcohol are added." The great solubility of the α— and the sparing solubility of the β— compound admit of an easy separation of the two nitroso-chlorides.

Physical Properties.

α–Nitrosochlorides.

The limonene α-nitroso-chlorides crystallize in tabular crystals of the monoclinic system[9]. The dipentene derivative does not crystallize as well[10]. The + and $-\alpha$-nitroso-chloride melt at 103—104°, whereas the dipentene derivative melts at 78°[11], but congeals to a crystalline mass immediately after, and melts a second time at 103–104°. The limonene derivatives are soluble in about an equal weight of chloroform and twice their weight of ether. These solutions are strongly optically active $[\alpha]_D = +313.4°$ resp. $-314.8°$ [13]. The dipentene derivative is more readily soluble, and is optically inactive.

β-Nitrosochlorides.

The limonene β-nitrosochlorides are precipitated from their chloroform solutions with methyl alcohol as woolly crystalline needles.[14] By careful crystallization from chloroform they can be obtained in handsome prismatic crystals.[15] The β-nitrosochlorides are much less soluble than the α-derivatives. Their optical activity is also not as great: $[\alpha]_D = + 240.3°$ resp. $-242.2°$ [16] The melting point has been found to vary, viz., 100–106° [14] Dipentene β-nitrosochloride, like the α-derivative, is more soluble, does not crystallize as well as its optically active modifications and melts at 101°. A third modification which melts at 75–76° has been observed.[17]

Chemical Properties.

The chemical properties of the α- and β-nitrosochlorides do not differ essentially and can, therefore, be considered together. When carefully heated by themselves (Tilden[3]), or when heated with alcoholic potassa (Wallach[18]) hydrogen chloride is split off and carvoximes result (Comp. also Goldschmidt[5]). Thus dextrogyrate limonene-nitrosochloride yields laevogyrate carvoxime, also obtainable from laevogyrate carvol; whereas laevogyrate limonene nitrosocloride yields dextrogyrate carvoxime, also obtainable from dextrogyrate carvol.[19] From dipentene nitrosochloride optically inactive carvoxime results, which can also be obtained by mixing solutions of equal parts of the optically active carvoximes.[20]

A molecule of hydrogenchloride can be added to form nitrosochloride-hydrochlorides, but these differ from the hydrochlor-nitrosochlorides.[21] The chlorine of the $\left\{\begin{matrix}\mathrm{NO}\\ \mathrm{Cl}\end{matrix}\right.$ group can easily be replaced by basic radicles whereby nitrolamine bases result. In these double decompositions α- and β-nitrosochloride behave alike.[22]

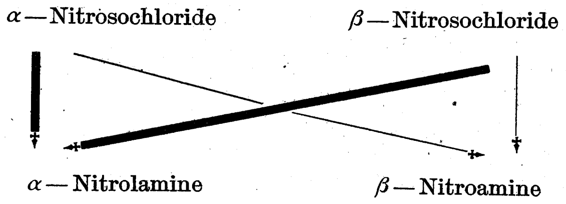
The nitrosochlorides are unsaturated. With bromine they yield an unstable dibromide (Tilden[1]). Their unsaturated condition is also recognizable from the *hydrochlor* nitrosochloride.

Nitrosates.

Thus far dipentene-nitrosate only has been described. There appears to be some difficulty connected with the preparation of the limonene-nitrosates.[23] Dipentene-nitrosate crystallizes in laminæ which melt at 84°. In its constitution it is analogous to the nitrosochloride; by splitting off nitric acid o–carvoxime results; by double decomposition with bases the optically inactive nitrolamine base results; apparently it adds a molecule of hydrogenchloride (molecular addition); its unsaturated condition becomes apparent from the hydrochlor nitrosate. Thus far a separation of two nitrosates, if such a mixture results at all, has not been effected.

Nitrolamines.

The double decomposition of terpinene nitrosite with bases on the part of Wallach induced this investigator to study the behavior of nitrosochlorides and nitrosates toward bases. Thereby the analogy between the nitrosochlorides $\left\{\begin{matrix}\mathrm{No}\\ \mathrm{Cl}\end{matrix}\right.$, nitrosites $\left\{\begin{matrix}\mathrm{No}\\ \mathrm{O\ (NO)}\end{matrix}\right.$ and nitrosates $\left\{\begin{matrix}\mathrm{NO}\\ \mathrm{O\ (NO_2)}\end{matrix}\right.$ was established. The application of this reaction proved especially favorable in the limonene group. Even before the nitrosochlorides were known to be a mixture the notrolanilids were recognized as such. Furthermore, it was ascertained that the separated α and β nitrosochlorides yielded each two, viz, an α and a β nitrolamine base, and that these α and β nitrolamine were respectively identical. The reactions may be expressed in the following manner:



α-Nitrolpiperidine[26]. $C_{10}\ H_{16}\left\{\begin{matrix}\mathrm{NO}\\ \mathrm{N.\ C_5\ H_{10}}\end{matrix}\right.$

Limonene-α-nitrol piperidine crystallizes from alcohol in handsome rhombic crystals which melt at 93–94°. In petroleum ether, in ether and chloroform it is readily soluble, less so in alcohol. The solutions turn the plane of polarized light in the direction of the underlying hydrocarbons: $[\alpha]_D = +\ 67,75°$ resp. $-\ 67,60°$. The hydrochlorides turn the plane of polarization in the opposite direction.

The *dipentene base* precipitates upon the mixture of the petroleum ether solutions of the optically active components. From alcohol it crystallizes in monosymmetric crystals which stand in no relation to the well formed crystals of its optically active modifications.

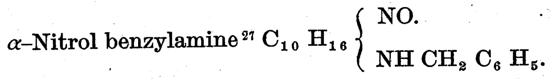
β- Nitrolpiperidine[26] $C_{10}\ H_{16}\left\{\begin{matrix}\mathrm{NO}\\ \mathrm{N.\ C_5\ H_{10}.}\end{matrix}\right.$

The *Limonene* derivatives melt at 110–111°, crystallize monosymmetrically, and are less soluble, especially in petroleum ether, than the

-compounds. The solutions turn the plane of polarized light in a direction opposite to that of the underlying hydrocarbon:

dextrogyrate-limonene-β-nitrolpiperidine $[\alpha]_D = -60,37°$.
lævogyrate " " " " $[\alpha]_D = +60,18°$.

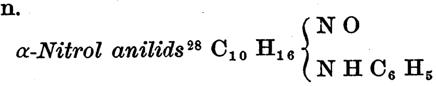
Their hydrochlorides are almost optically inactive. The *dipentene* base stands in similar relation to its components as does the α-base to its. It melts at 152°.


$$\alpha\text{-Nitrol benzylamine}^{27}\ C_{10}H_{16}\begin{cases} NO. \\ NH\,CH_2\,C_6H_5. \end{cases}$$

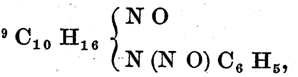
The *limonene* α-nitrol benzylamine crystallizes from alcohol in hard needles which possess no sharply defined crystal faces. It melts at 93°. It is optically strongly active turning the plane of polarized light in the same direction with the underlying hydrocarbon; $[\alpha]_D = +163.8°$, resp. $-163.6°$. The salts of this base are sparingly soluble in water, more readily in alcohol. Their rotatory power is without exception opposite to that of the free base.

dextrogyrate-limonone α-nitrol benzylamine-chlorhydrate $[\alpha]_D = -82.26°$.
lævogyrate-limonone α-nitrol benzylamide-chlorhydrate $[\alpha]_D = +83.06°$.
dextrogyrate-limonene α-nitrol benzylamine-nitrate $[\alpha]_D = -81.5°$.
lævogyrate-limonene α-nitrol benzylamine-nitrate $[\alpha]_D = +81.0°$.
dextrogyrate-limonene α-nitrol benzylamine-d-tartrate $[\alpha]_D = -49.98°$.
lævogyrate-limonene α-nitrol benzylamine-d-tartrate $[\alpha]_D = +69.6°$.
dextrogyrate-limonene α-nitrol benzylamine-l-tartrate $[\alpha]_D = -69.9°$.
lævogyrate-limonene α-nitrol benzylamine-l-tartrate $[\alpha]_D = +51.0°$.

The *β-Nitrol benzylamines* have not yet been obtained in a pure condition.

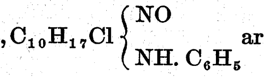

$$\textit{α-Nitrol anilids}^{28}\ C_{10}H_{16}\begin{cases} N\,O \\ N\,H\,C_6H_5 \end{cases}$$

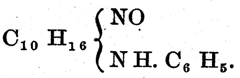
The *limonene* derivatives crystallize, when pure, from dilute alcohol in hard, colorless, tabular crystals which melt at 112–113°. Their action upon polarized light corresponds to that of the underlying hydrocarbons, viz.: $[\alpha]_D = +102.25°$ resp. $-102.62°$. The hydrochlorides are sparingly soluble in water, more readily in alcohol. Their solutions deviate the ray of polarized light but little, however, in the same direction as do the free bases.

The *α-Nitroso-derivatives,*[29]  $C_{10}H_{16}\begin{cases} NO \\ N(NO)C_6H_5, \end{cases}$ crystallize in white blunt needles and melt at 142°. Their solutions deviate the ray of polarized light in the direction as do the underlying bases, but the action is lessened, viz.: $[\alpha]_D = +46.20°$ resp. $-47.82°$

Dipentene-α-nitrolanilid crystallizes from a mixture of alcoholic solutions of equal parts of the limonene derivatives and melts at 125-126°.

The *dipentene nitroso-compound*[29] is obtained in the same way from its components. It is less soluble than the latter, crystallizes better, i. e., in triangular tablets and melts at 147°.

The *Nitrolanilids,* like the nitroso-chlorides, are unsaturated compounds and can take up a molecule of hydrogen chloride. The α-hydrochlor addition products,  $C_{10}H_{17}Cl\begin{cases} NO \\ NH.\,C_6H_5 \end{cases}$ are identical with the hydrochlor nitrol anilids to be described later.

β-Nitrolanilids[28]  $C_{10}H_{16}\begin{cases} NO \\ NH.\,C_6H_5. \end{cases}$

The limonene β-nitrolanilids are somewhat filty needles, which are almost insoluble in water and petroleum ether, readily soluble in hot benzol, but difficultly in cold benzol and in ether, more readily soluble in alcohol and chloroform. Whereas the solutions of the β-compounds are not precipitated. The latter thus appear to be stronger bases. Melting-point 152°. Optically they act in a direction opposite to that of the underlying hydrocarbons and thus differ from the β-derivatives.

dextrogyrate-limonene β-nitrolanilid $[\alpha]_D = -89.39°$.

lævagyrate-limonene β-nitrolanilid $[\alpha]_D = +87.17°$.

Their *nitroso-derivatives*[29], however, which melt at 136° again turn the plane of polarized light corresponding in direction to that of the underlying hydrocarbon. Their specific rotatory power is by (about) 10° stronger than that of the corresponding α derivatives:

dextrogyrate-β-nitrol-nitroso-anilid $[\alpha]_D = +57{,}67°$

laevogyrate-β-nitrol-nitroso-anilid $[\alpha]_D = -57{,}75°$

Dipentene β nitrol nitroso anilid, obtained from its optically active components, does not crystallize well and melts at 129°.

The *β-hydrochlor addition products*[30] differ from the α-compounds and have thus far not been obtained from the hydrochlor-nitrosochlorides.

The *limonene* derivatives crystallize from alcohol in beautiful, hexagonal tablets and melt at 78°. They are not at all strongly optically active, but turn the plane in a direction corresponding to that of the underlying hydrocarbons. $[\alpha]_D = + 12.91°$ resp. $— 12.51°$. The hydrochlor addition product of *Dipentene-β-nitrol-anilid* crystallizes from its alcoholic solution in four sided prisms and melts at 90°.

Hydrochlor, Nitrosochlorides, Nitrosates and Nitrolamines.

Through the action of hydrochloric acid, amyl nitrite and nitric acid upon "carvene" Maissen obtained a "compound $C_{10}H_{16}\left\{\begin{matrix}NO & Cl\\ NO_3 & H\end{matrix}\right.$" which Wallach recognized as hydrochlornitrosate, $C_{10}H_{17}Cl. NO (O. NO_2)$. Later it was shown that this compound was a dipentene and not a limonene ("carvene") derivative. The corresponding hydrochlor-nitrosochloride was first prepared by Wallach. The optically active modifications were prepared by me in Prof. Wallach's laboratory.

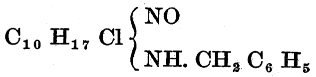
The hydrochlor-nitrosochlorides, etc., are saturated compounds. They can be regarded as nitrosochlorides, nitrosates and nitrolamines of the monhydrochlorides of the limonene hydrocarbons. Thus far all of the saturated nitrosochlorides, etc., prepared from *monhydrochlor limonene*, have been obtained in but one modification, which corresponds to the α–modification of the unsaturated derivatives free from chlorine.

Hydrochlor nitrosochlorides[31] $C_{10}H_{17}Cl\left\{\begin{matrix}NO\\ Cl\end{matrix}\right.$

The limonene derivatives crystallize poorly, melt at 92-93° without decomposition. $[\alpha]_D$ for the dextrogyrate compound $= +173.71°$. The crude product is largely contaminated by the dipentene modification. The latter apparently posseses a higher melting point, viz, 109°. Like the unsaturated nitrosochlorides they split off hydrochloric acid, however, to form hydrochlorcarvoximes.

Hydrochlor-nitrosates[32] $C_{10}H_{17}Cl\left\{\begin{matrix}NO\\ O(NO_2)\end{matrix}\right.$

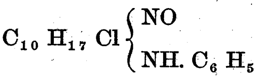
The *limonene* derivatives can be obtained in handsome pearly prisms. They melt at 108° decomposing at the same time. $[\alpha]_D$ for the dextrogyrate compound $= +61.34°$. The *dipentene* hydrochlor-nitosrate also melts at 108-109° and is readily distinguished by its optical activity. From it a molecule of nitric acid can be split of with the aid of dimethylanilin[33] anologous to the hydrochlor carvoxime reaction. The resulting product crystallizes from an ethyl-alcoholic solution with a molecule of $C_2 H_5 O H$, from a methyl-alcholic solution wit a molecule of $C H_3 O H$.

Hydrochlor-nitrolbenzylamine,[34]

$$C_{10} H_{17} Cl \left\{ \begin{matrix} NO \\ NH.\ CH_2\ C_6\ H_5 \end{matrix} \right.$$

The *limonene*-derivatives were obtained in white filty needles, which melt at 103–104.° They turn the plane of polarized light as do the underlying hydrocarbons: $[\alpha]_D = +149.6°$ resp. $-147.4.°$

The chlorhydrates crystallize from alcohol in small needles which melt and decompose at 163–164.° The action upon polarized light corresponds to that of the free bases though weakened: $[\alpha]_D = +46.97°$ resp. $-50.9.°$

The *dipentene-hydrochlor-nitrol-benzylamine* crstallizes better than its optically active components, melts at 150° and is but difficultly soluble. Its hydrochlorate, however, is more soluble than its components, but possesses the same melting point.

Hydrochlor-nitrolanilids,[35]

$$C_{10} H_{17} Cl \left\{ \begin{matrix} NO \\ NH.\ C_6\ H_5 \end{matrix} \right.$$

The limonene-derivatives crystallize from ether in handsome colorless flat prisms. Melting point 117–118° $[\alpha]_D = +126.95,°$ resp. $-122.34.°$

Dipentene-hydrochlor-nitrolanilid, prepared synthetically is colorless and melts at 140–141.° When hydrogen-chloride is split off α- and β- nitrol anilids apparently result.[36]

REFERENCES.

Dextrogyrate Limonene:

[1] Ann. Chim. Phys. T. 52.
[2] Annalen, Bd. 6, p. 259.
[3] J. Pharm, T. 26, p. 1.
[4] J. pr. Chem. Bd. 24, p. 257.
[5] Ann. Chim. Phys. [3] T. 37.
[6] Ibidem, T. 38.
[7] Ibidem, T. 39.
[8] Annalen, Bd. 35, p. 308.
[9] Ibidem, Bd. 85, p. 246.
[10] J. C. S., Vol. 17, p. 1.
[11] Ibidem, Vol. 24, p. 1186.
[12] Ibidem, Vol. 31, p. 549.
[13] Berichte, Bd. 6, p. 915.
[14] Ibidem, Bd. 5, p. 94.
[15] Ibidem, (1874) p. 627.
[16] J. C. S., 1877, Vol. 1, p. 554.
[17] Annalen, Bd. 225, p. 311.
[18] Ibidem, p. 318.
[19] Ibidem, Bd. 227, p. 290 and 291.
[20] Ibidem, p. 277.
[21] Ibidem, p. 289.
[22] Ibidem, Bd. 246, p. 222.

Lœovgyrate Limonene.

[1] Ann. Chim. Phys. [3] T. 37, p. 80.
[2] Annalen, Bd. 227, p. 287.
[3] J. C. S., Vol. 47, p. 779.
[4] Annalen, Bd. 246, p. 222.
[5] Dissertation, p. 16.

Dipentine.

[1] Ann. Chim. Phys. T. 52.
[2] Annalen, Bd. 6, p. 259.
[3] Ibidem, Bd. 27, p. 40.
[4] J. Pharm., T. 26, p. 1.
[5] J. pr. Chem., Bd. 24, p. 257.
[6] Annalen, Bd. 89, p. 358.

[7] Jahresber. f. Chem. f. 1854, p. 591 (Zeitschr. Pharm. 1854 pp. 3, 17, 65, 180.) Jahresber. f. Chem. f. 1855, p. 655 (Zeitschr. Pharm. 1855, pp. 2, 33, etc.)

[8] Royal Society of London Proceedings; vol. 10, p. 516.

[9] Bercihte, Bd. 5, p. 677.

[10] Compt. rend. T. 79, p. 223.

[11] Ibidem, T. 102, p. 50.

[12] Chem. News, vol. 46, p. 120.

[13] J. S. C., vol. 49, p. 316.

[14] Graebes "Cynen" is cymol, comp. also Wallach, Annalen, Bd. 225.

[15] Annalen, Bd. 225, p. 314.

[16] Ibidem, Bd. 227, p. 278.

[17] Ibidem, p. 301.

[18] Ann. Chim. Phys., T. 13, p. 259.

[19] Annalen, Bd. 67, p. 362.

[20] Ann. Chim. Phys. [3] T. 27, p. 80.

[21] J. C. S., vol. 49, p. 316.

[22] Compt. rend., T. 102, p. 50.

[23] Berichte, Bd. 12, p. 2354 and
Bd. 20, p. 1956.

[24] Compt. rend., T. 106, p. 663.

[25] Compare Ann. Bd. 252, p. 128.

[26] Compt. rend., T. 106, pp. 1419 and 1538.

[27] Annalen; Bd. 38, p. 111.

[28] ibidem Bd. 87, p. 312.

[29] Arch. d. Pharm., [2] Bd. 111, p. 104.

[30] Annalen, Bd. 128, p. 293.

[31] Berichte, Bd. 7, p. 1427.

[32] Berichte, Bd. 17, p. 1970, (sent in Aug. 14th, 1884.)

[33] Annalen, Bd. 192, p. 222.

[34] This view is confirmed by Wallach. But as Faust & Homeyer, in judging Voelckel's analyses (these are stated to agree better with cymol, $C_{10} H_{14}$) apparently did not consider that Voelckel had used $P_2 O_5$ in dehydrating cineol, so Hell & Stürcke overlook the fact that Faust & Homeyer employed $P_2 S_5$. Wallach has shown that phosphorus pentasulphide easily converts cynene (dipentene) into cymol.

[35] Berichte, Bd. 17, p. 1975. ("Eingelaufen am 14, Aug. 1884.")

[36] Annalen, Bd. 225, p. 291. ("Eingelaufen am 10, Aug. 1884.")

[37] Ibidem, p. 314 and [18] p. 317.

[38] Ibidem, Bd. 227, p. 277.

[39] Compare Annalen, Bd. 245, p. 197.

[40] Ibidem, Bd. 246, p. 221.

[42] Ibidem, p. 228.

[43] Ibidem, p. 230.

Properties, etc.

[1] Annalen, Bd. 227, p. 291 and 301.

[2] Ibidem, Bd. 252, p. 144.

[3] Ibidem, Bd. 246, p. 222.

[4] Dissertation, p. 38.

[5] Compare also F. Scheidt, "Ein Beitrag zur Kenntniss der Terpene Bonn, 1890.

[6] Annalen, Bd. 252, p. 145.

[7] Ibidem, Bd. 246, p. 224.

[8] Dissertation, p. 9.

[9] Berichte, Bd. 12, p. 2357 and
Ibidem, Bd. 20, p. 1956.

[10] Dissertation, p. 51.[1]

[11] Dipentene is always found as an impurity in artificial terpinene Annalen, Bd. 230, p. 261, and
Ibidem, Bd. 239, p. 38.

[12] Annalen, Bd. 230, pp. 247 and 262, and
Ididem, Bd. 239, pp. 2, 23 and 51.

[13] Oppenheim; Berichte, Bd. 6, p. 915, and
Ibidem, Bd. 7, p. 627.
Wright: J. C. S., vol. 21, p. 686.

[15] Only such data were considered that were deemed sufficient proof i. e. those in which optical properties are included.

[16] 1840 — Soubeiran & Capitain, J. d. Pharm., T. 26, p. 1. 1885 — Wallach, Annalen, Bd. 227, p. 290.

[17] 1840 — Soubeiran & Capitain[16]. 1877 — Tilden, J. C. S., Vol. I., p. 554. 1884 — Wallach — Annalen, Bd. 225, p. 318.

[18] 1854 — M. Berthelot, Ann. Chim. Phys. T. 40, p. —.

[19] 1857 — S. de Luca, Compt. rend., T. 45, p. 904.

[20] 1885 — Wallach, Annalen, Bd. 227, p. 290.

[21] Ibidem, p. 291.

[22] Ibidem, p. 292.

[23] Ibidem, p. 292.

[24] 1885 — Yoshida, J. C. S., Vol. 47, p. 787.

[25] 1888 — Wallach, Annalen, Bd. 246, p. 221.

[26] Annalen, Bd. 252, p. 109.

[27] Ibidem, p. 111.

[28] Ibidem, pp. 121 and 136.

[29] Ibidem, Bd. 227, p. 296.

[30] Ibidem, Bd. 238, p. 80.

[31] Ibidem, Bd. 252, p. 102.

[32] Ibidem, p. 101.

[33] Ibidem, Bd. 230, p. 224 and Bd. 239, p. 26.

[34] Ibidem. p. 246.

[35] J. C. S. ——

[8] Eberhardt, Arch. d. Pharm., Bd. 225, p. 515.

[37] Wallach speaks of "aus Wurmsamenöl erhältlichem cynen," but he obtained this "cynen" with the aid of chemical reagents, by means of which cineol is converted into dipentene. The hydrocarbon occuring in these oils no doubt is dipentene, but the experimental proof is wanting. Comp. e. g. E. Jahns, "Ueber das Eucalyptol." Archiv d. Pharm., Bd. 223, p. 52.

[38] Method of preparation, Annalen, Bd. 239, p. 3.

[39] Ibidem, Bd. 252, pp. 127 and 136.

[40] Ibidem, Bd. 227, p. 295., Comp. Diisoprene of Bouchardat.

[41] [1] Comp. Wallach: " Am. Terpentinöl., Fichtennadelöl, Wachholderbeerenöl, Macisöl, Salbeiöl, Citronenöl." Annalen, Bd. 227, p. 277 et seq.

[2] (*a.*) That under certain conditions pinene will not form artificial camphor but dipentene dihydrochloride was first shown by Berthelot (1852.) Comp. historical sketch. Also Wallach, Annalen, Bd. 227, p. 286.

(*b.*) The inversion of pinene into dipentene by means of sulphuric acid was studied by Armstrong and Tilden; Berichte, Bd. 12, p. 1754. Wallach, Annalen, Bd. 227, p. 283.

[3] Compare Terpinhydrate.

[42] [1] Comp. Wallach: " Pomeranzenschalenöl, Fichtennadelöl, Annalen, Bd. 227, p. 277.

[2] Comp. historical shetch, also Dissertation, p. 38.

[3] Comp. Disertation p. 46 [9]. Hydrochloric acid acts like nitric acid: Annalen, Bd. 230, p. 266, Dissertation p. 45.

[43] Annalen, Bd 239, p. 44.

[45] Annalen. Bd. 239, p. 4.

[46] Annalen, Bd. 245. p. 196.

[47] Annalen, Bd. 230, p. 247 et. seq.

Ad. Monhydrochlorides.

[1] Journ. de Pharm., T. 26, p. 1.

[2] Ann. Chim. Phys., [3] T. 37.

[3] Compt. rend. T. 45, p. 904.

[4] Ibidem, T. 79, pp. 223 and 315. (J. C. S. Vol. 32, p. 1162.)

[5] Ibidem, T. 80, p. 1446. (J. C. S. Vol. 33, p. 1259.)

[6] Gazetta Chimica, T. 13, p. 99. (Berichte, Bd. 16, p. 1241.

[7] Compare e. g.:
Himly (1835) Annalen, Bd. 29, p. 40.
Schweizer, (1840) J. pr. Chem., Bd. 24, p. 257.

[8] Annalen, Bd. 239, p. 10.

[9] Ibidem, Bd. 241, p. 324.

Ibidem, Bd. 245, pp. 241 et. seq. (p. 248, also pp. 258–260.)

[10] Dissertation, p. 55.

[11] Ibidem, p. 40.

[12] Annalen, Bd. 245, p. 249.

[13] Ibidem, Bd. 245, p. 259.

[14] Ibidem, p. 260; Dissertation p. 46.

[15] Ibidem, p. —; ibidem p. 49.

[16] Dissertation, p. 45.

[17] Annalen, Bd. 230, p. 265.

[18] Ibidem Bd. 245, p. 259; Dissertation, p. 41.

It is of interest to note that the addition of one molecule of hydrogen chloride renders limonene more apt to polymerize. Disregarding the crystalline camphene (no doubt also fenchene) the terpenes with one double bond apparently polymerize more readily than those with two.

[19] Dissertation, p. 43.

[20] Ibidem, p. 39.

[21] Annalen, Bd. 245, p. 250.

[22] Dissertation, p. 51, etc.

ad Dihydrohalogen addition products.

[1] Ann. Chim. Phys., T. 13, p. 259.

[2] Ibidem, T. 52.

[3] Dumas proposes the ending êne for the hydrocarbons from volatile oils to avoid confusion with the alkaloids.

[4] Annalen, Bd. 6, p. 259.

[5] Ibidem, Bd. 27, p. 40.

[6] Ann. Chim. Phys. T. 66, p. 196.

[7] Comp. Monohydrochlorides — note [4].

[8] J. de Pharm. T. 26, p. 1.

[9] J. pr. Chem., Bd. 24, p. 257.

[10] Annalen, Bd. 67, p. 362.

[11] Ann. Chim. Phys. [3] T. 37.

[12] Ibidem [3] T. 61, p. 463.

[13] According to the nomenclature proposed by Berthelot in his "Chimie organique fondée sur la synthese" T. *II*, p. 735.

[14] Annalen, Bd. 129, p. 149.

[15] J. C. S., vol. 47, p. 787.

[16] Berichte, Bd. 17, p. 1975.

[17] Annalen, Bd. 227, p. 301, and Ibidem, Bd., 239, pp. 12 and 13.

[18] Compt. rend., T. 102, p. 433.

[19] The original names of these derivatives already indicate this fact. To the pinene monhydrochloride alone the term artificial camphor

("camphre artificiel") could be applied on account of its camphor like odor. The dipentene dihydrochloride, which has not the least resemblance with natural camphor could be called "camphre artificiel de citron" only because it was prepared from a similar natural product and in an analogous manner. The "camphre artificiel" proper was thereafter also termed "camphre artificiel de térébenthine."

[20] Memoirs de la Société D'Arcueil, T. 2, p. 23.

[21] Annalen, Bd. 27, p. 40.

[23] Ann. Chim. Phys. [3], T. 27, p. 80.

[24] J. C. S., vol. 17, p. 1.

[25] Table of melting points in chronological order:

1833. Blanchet & Sell, 43°.
1840. Soubeiran & Capitain, 50°.
1840. Schweizer, 50°.
1862. Oppenheim, 48°.
1884. Hell & Ritter 50-51°.
1885. Yoshida 58-59°.
1887. Weber 50° (Amalen, Bd. 238, p. 102).
1887. Wallach 50° (Ibidem, Bd. 239, p. 12).

[26] Can therefore be precipitated from its solution in glacial acetic acid with the aid of water.

[27] Tilden: Berichte, Bd. 12, p. 1131.
Wallach: Annalen, Bd. 239, p. 5.

[28] Wallach Ibidem, Bd. 230, p. 260.

[29] Wallach Ibidem, Bd. 239, p. 12. (Comp. B. & S. [4]).

[30] Comp. Dipentene: Regeneration.

[31] Annalen, Bd. 246, p. 267.

[32] First observed by Riban: Compt. rend. T. 79, pp. 223 & 314.
Confirmed by Wallach: Annalen, Bd. 245, p. 247.

[33] Comp. historical sketch.

[34] Hell & Ritter (1884): Berichte, Bd. 17, p. 1975.
Wallach & Brass (1884): Annalen, Bd. 225, p. 298.

[35] First observed by List[10] (1848) verified by Deville (1849); Ann. Chim. Phys. [3], T. 27, p. 80, and others, Wallach: Annalen, Bd. 230, p. 248 and ibidem, Bd. 239, p. 18.

[36] Oppenheim[14] (1862).

[37] Wallach: Annalen, Bd. 230, p. 265.

Comp. also Flawitzky; (1879) Berichte, Bd. 12, p. 2354 and (1887) ibidem, Bd. 20, p. 1956.

Bouchardat & Lafont (1886), Compt. rend., T. 102, p. 433.

[38] Berthelot[11] (1852).

[39]&[40] Annalen, Bd. 239, p. 44.

[41] Ibidem, Bd. 245, p. 267.

[42] Ann. Chim. Phys. [3], T. 61, p. 463.

[43] Annalen, Bd. 239, p. 13.
[44] Ibibem, p. 24.
[45] Ibidem, p. 3.
[46] Ibidem, Bd. 57, p. 247.
[47] Ibidem, Bd. 225, p. 302.
[48] Ibidem, Bd. 230, p. 249.
[49] Ibidem, p. 265.
[50] Ibidem, Bd. 239, p. 14 and Bd. 252, p. 128.
[51] Ibidem, Bd. 230, p. 249.

ad Terpinhydrate.

[1] According to Gmelin "Hand-book of Chemistry" 1860, vol. 14, p. 258.
[2] Repert. **9**, 276, and **22**, 419.
[3] N. Journ. d. Ph., Bd. 15, St. 2, p. 46.
[4] Jahresbericht **27**, p. 440.
[5] Annalen, Bd. 67, p. 362. List distinguishes between "Krystallisirtes Terpin $C^{20} \dot{H}^{17} 0 + 3 H + 2$ aq.," and "Terpin ohne Krystallwasser, $C^{20} \dot{H}^{17} 0 + 3 H$," p. 375.
[6] Annalen, Bd. 6, p. 267.
[7] Ibidem, Bd. 7, p. 167.
[8] Ididem, Bd. 33, p. 358.
[9] Ibidem, Bd. 52, p. 390.

List[5] rejects this term because according to his views the elements of water in the terpin are not present as "Hydratwasser." He also rejects the term "Terpentin campher" as inappropriate. He accepts the nomenclature of Bezilius[4–5]:

[10] Ann. Chim. Phys. [3] T. 27, p. 80. (Annalen, Bd. 71, p. 348.)
[11] Annalen, Bd. 230, p. 247.
[12] Ann. Chim. Phys., T. 57, p. 334 (1835). (Annalen, Bd. 14, p. 75.

The analyses of Dumas and Peligot pertain to crystals found in turpentine oil (*a*), in basilicum oil (Acimum basilicum, L) (*b*) and in cardamom oil (cardamomum minus) (*c*). They assign to these substances the formula $C_{40} H_{32} + H_{12} O_6$ and believe them to be *identical.* No doubt these crystals were terpin hydrate as also those obtained by Rammelsberg (Annalen, Bd. 52, p. 391.) from a mixture of turpentine oil, hydrochloric acid, "Spiritus cochleariae" and "Spiritus Serpylli."

[13] Blanchet and Sell mention Buchner,[2] Boisonot, Persot, Cluzel and Geiger (Mag. Pharm. **16**, 64), as chemists who have investigated "Terpenthin campher." B. & S. had not prepared the substance themselves but had recived it from Prof. Geiger who *probably* obtained it by heating moist turpentine oil for some time at a temperature of 50°. Based upon their analysis of the ("nicht vollkommen von anhangendem Oele

befreiten,") substance they assign to it the formula $C^{10} H^{16} + H^4 O^2 = C^{10} H^{20} O^2$, consisting therefore "aus einem Atom Terpenthinöl und einem Atom Wasser."

Blanchet (Annalen, Bd. 7, p. 167) obtained "Terpenthinhydrat" "durch vermischen des Oels (Wacholderbeerenoel) mit Wasser und hinstellen desselben in gewöhnlicher Temperatur, wo denn nach einigen Wochen das Hydrat *an den oberen Wänden des Gefässes krystallisirt.*" According to such a method pinol hydrate is obtained, not terpin hydrate.

[14] That Stenhouse, according to Wiggers' method, should not have obtained terpin hydrate, but a substance "$C_5 H_4 + HO$" (i. e. $C_{10} H_{20} O_2$) seems strange indeed. Analyses, physical properties and the odor of the dehydration product do not harmonize with those of terpin-hydrate, but with those of pinol-hydrate.

[15] Attempting to prepare terpin hydrate in one experiment (Annalen, Bd. 57, p. 247) Wiggers obtained according to his well known method "campher" within half an hour, which, however, disappeared after several hours. After that no further crystals would result. It would appear from the text that Wiggers had shaken the bottle whereupon the crystals dissolved. Under these conditions pinol hydrate might form in so short a time, but not terpin-hydrate.

List (Annalen, Bd. 67, p. 362) essentially verifies Wiggers' statements, and calls special attention to the fact that one molecule of water in terpin hydrate is present as water of crystallization.

Deville (Annalen, Bd. 71, p. 346) adds very little new. It is of interest, however, to note that he recognized the *identity* of the dipentene dihydrochloride obtained from terpin hydrate with that obt. from lemon oil.

[16] Sobrero first recognized the fact that by the action of oxygen in the presence of sunlight a hydrate is formed which differs from the "Terpentinölhydrat" of Wiggers. He assigns to it the formula "$C_{20} H_{16} O_2 + 2 H O$" [i. e., $C_{10} H_{18} O_2 = C_{10} H_{16} O + H_2 O$]. This substance recently designated as "soberol" by Armstrong (J. C. S., vol. 49, p. 315), is nothing more or less than Wallach's pinol hydrate (Annalen, Bd., 259, p. 313.)

[17] A compilation of the various crystallagraphic measurements can be found in Rammelsberg "Handbuch d. kryst. phys. Chemie." (1882) p. 449.

[18] According to Vulpius, J. C. S., 56, 1202 (from Chem. Centr., 1889, p. 789, from Pharm. Centralhalle, 30, 289.) The statement that terpinhydrate is soluble in 200 p. of cold and 22 p. of boiling water (Realencyclopædie der gesammten Pharmacie IX, p. 645) can be traced back to Blanchet and Sell (Annalen, Bd. 6, p. 266). It has been indicated that these chemists very likely had no terpin hydrate in hand but pinol hydrate.

[19] An alcoholic solution does *not* decolorize bromine; Wallach: (Annalen, Bd. 230, p. 248.)

[20] Ibidem.

[21] Ibidem, p. 271. The details of the dehydration experiments, p. 253.

[22] Ibidem, Bd. 239, pp. 18, 20, 23.

[23] Comp. Dipentene dihydrochloride: Historical notes.

[24] Observed first by Berthelot (Ann. Chim. Phys. [3] T 61, p. 463.)

[25] Comp. Dipentene dihydriodide: Historical notes.

[26] Oppenheim (1862). Annalen, Bd. 129, p. 149.

[27] Wallach, Ibidem, Bd. 239, p. 19.

[28] Ibidem.

[29] Ibidem, p. 20.

Oxidizing terpin with nitric acid Hempel (Annalen, Bd. 180, p. 71) obtained besides carbonic and oxalic acids chiefly toluic acid, $C^8 H^8 O^2$, terephthalic acid and terebinic acid $C^7 H^{10} O.^4$ Oxidizing terpin with chromic acid he obtained terpenylic acid $C^8 H^{12} O^4 + H^2 O$. Already in 1856 Personne (Annalen, Bd. 100, p. 253) had obtained "Terebentilsäure $C_{16} H_{10} O_4$" by passing the vapor of terpin over hot soda-lime.

[30] Ibidem, Bd. 246, p. 267.

[31] Ibidem, Bd. 230, p. 249.

[32] Dissertation, p. 49.^{9}

[33] The first reliable method is that of Wiggers. Tilden obtained the same product from American and French oil of turpentine. The hydration takes place in the presence of acids:

1. Of nitric acid — Wiggers, Mansfield.
2. Of muriatic acid — Rammelsberg (Annalen, Bd. 52, p. 390.)

[3. Of sulphuric acid — Tilden, Wallach.]

[34] That the regeneration of terpin hydrate from terpineol takes place within a few days in the presence of dilute acids was observed by Tilden and confirmed by Wallach (Annalen, Bd. 230, p. 266).

[35] Dissertation, p. 45.

[36]	Oil.	Nitric Acid.	Alcohol.		
Wiggers.	8	2 (Sp. grav. 1.25 — 1.3) ..	1 (80 p. c.)..	Temp. 20-25°. Largest yield after 2 yrs. 1 oz. from 1 lb. oil.........	Annalen **57**, 247.
Deville...	4	1 (Commercial).	3 (85 p. c.)	From 4 l. after 6 weeks 250 g: abt. 7.2 p. c....	Ibidem, **71**, 348.
	8	2 (Commercial).	6 (85 p. c.)		(Ann. Chim. Phy. [3] **25**, 80.)
Hempel..	8	2 (Sp. grav. 1.25 — 1.3) ..	2	....	Annalen **180**, 73.
Tilden....	2½	1 (Sp. gr. 1.4)...	1	Tilden claims to have obtained a yield of abt. 33 p. c...........	
	8	3.5	3.5		J. C. S. **33**, 248.
Schmidt..	8	2 (Sp. grav. 1.18) ..	2	....	Pharm. Chem. II., 818.

ad Terpineol.

[1] Although much has been written about "Wiggers' terpinol" this term did not originate with Wiggers, but with List. List's terpinol is not identical with Wallach's terpineol but a mixture of the latter substance with hydrocarbons $C^{10} H^{16}$ (probably dipentene and terpinene). However, Berthelot[3] already employed the term terpinol for a substance $C^{10}H^{18}O$, whereas Oppenheim[4]. falls back upon List's formula $C^{20} H^{34}O$, although he acknowledges that the substance under consideration is most likely no chemical unit and even quotes Gerhardt[4], who does not believe in the existence of such a body. Tilden[5]. again declares List's terpinol to be a mixture, nevertheless he retains the term for his monatomic alcohol $C^{10} H^{18}O$. The same must be said of Tanret[6].

[2] Annalen, Bd. 67, p. 362.

[3] Ibidem, Bd. 83, p. 106. (Compt. rend., T. 34, p. 799.)

[4] Ibidem, Bd. 129, p. 149.

[5] J. C. S., Vol. 33, p. 247, and
Ibidem, Vol. 35, p. 286.

[6] Ibidem, Vol. 48, p. 990. (J. de Pharm. [5] T., 11, p. 506.

[7] Berichte, Bd. 12, p. 2354, and
Ibidem. Bd. 20, p. 1956.

[8] Annalen, Bd. 230, p. 254.*

[9] Compt. rend. T. 104, p. 996.

[10] Annalen, Bd. 57, p. 252.

[11] Compt. rend., T. 102, pp. 50, 318, 433 and 1155.

[12] Ibidem, T. 54 ?, p. 845.

[13] Bouchardat and Voiry[9] claim to have obtained crystals of "tepilenol" prepared from terpin, that melted at 30–32°.

[14] Annalen, Bd. 230, p. 265.

[15] Terpineol from its acetate (from pinene) 218-223° B. & L.[11]
Terpineol from terpinhydrate 218° B & V.[9]
"R-Terpenhydrat" of Flawitzky[7] 213.7-217.7°.
"L-Terpenhydrat" of Flawitzky[7] 217.7-220.7°.

[16] Comp. "Cautschene Monochlorhydrate" B. & L.[11]
Comp. Terpineol, Wallach, Annalen, Bd. 239, p. 21.

[17] From acetate prep. from —pinene $[\alpha]_D = -64.3^\circ$ B. & L.[11]

"L-Terpenhydrat of Flawitzky"[7] $[\alpha]_D = -56.2^\circ$.

"R-Terpenhydrat of Flawitzky"[7] $[\alpha]_D = +48.4^\circ$.

"Terpilenol" from citrene through the acetate $[\alpha]_D = +67^\circ 31'$ Lafont.[12]

[18] Spec. Gravity = 0.961 at 0°, Bouchardat & Lafont.[11]
0.952 Bouchardat & Voiry.[9]

$$\left.\begin{array}{l}0.9339 \text{ at } 0^\circ\\ 0.9340 \text{ at } 0^\circ\end{array}\right\}\text{ Flawitzky.}^{7}$$

$$\left.\begin{array}{l}0.940 \text{ at } 15^\circ\\ 0.935 \text{ at } 20^\circ\end{array}\right\}\text{ Schimmel \& Co., Bericht, Oct '90, p. 52.}$$

[19] It readily absorbs bromine. The bromide, however, is solid at very low temperatures only. Allowed to stand with an excess of bromine dipentene tetrabromide is formed. Wallach, Annalen, Bd. 230, p. 266.

[20] Tilden already observed that in alcoholic solution of "terpinol" acidulated with nitric acid crytals of terpinhydrate are generated J. C. S. vol. 33, p. 250. Wallach observed that very dilute hydrochloric or sulphuric acids at *ordinary temperatures* favor the addition of water.

[21] Since terpinene and terpinolene are products of inversion of limonene and dipentene the terpineols and terpin must be regarded as derivatives of the hydrocarbons of the limonene group, but not of the pinene group. This view is supported by the conversion of the terpineols into dipentene tetrabromide[19] and into the dihydrohalogen derivatives of dipentene.

[22] Comp. historical notes: Wallach (1885).

[23] List, Annalen, Bd. 67, p. 370.
Tilden, J. C. S., vol. 33, p. 249.

[24] Wallach, Annalen, Bd. 230, p. 267.
Flawitzky, Berichte, Bd. 20, p. 1960.

[25] From the method of formation of the monochlorhydrates of the limonenes we know that by the action of hydrogen chloride upon terpineol the monochorine ester (if this is identical with limonene monohydrochloride) could not be found. In this reaction water would be generated and thus the conditions favorable to the formation of the monochloride would be destroyed. For the formation of terpin-hydrate from the monochloride comp. Dissertation p. 45.

[26] Oppenheim, Annalen, Bd. 129, p. 157. This substance also appears to result from the action of acetic acid on pinene (B. and L.[11]), upon limonene (L[12]) and upon dipentene (B. and L.[11])

[27] Comp. methods of formation of terpin hydrate, also Wallach, Annalen, Bd. 239, p. 19.

[28] Wallach, ibidem, p. 21.

[29] Wallach, ibidem, Bd. 230, p. 267.

[30] Wallach, ididem, Tilden, J. C. S., vol. 35, p. 288.

[31] Annalen, Bd. 246, p. 267.

[32] ad I. Terpene hydrates of Flawitzky[7].

ad II. List[2]: by means of very dilute sulphuric acid (p. 367.)
Berthelot[3]: action of heat alone, chlorides of zinc, calcium strontium and ammonium, fluoride of calcium.
Tilden[5]: by means of dilute hydrochloric acid, (p. 248.
Wallach[8]: by means of dilute sulphuric acid, phosphoric acid, glacial acetic acid and potassium disulphate.

ad III. [1] Bouchardat and Lafont[11]: Acetates from pinene and dipentene.
Lafont[12]: Acetate from + limonene.
[2] Oppenheim[4]: Dipetene 2 H Br. with silver acetate (p. 154.)
Oppenheim[4]: Dipentene 2 H I with ammonia (p. 156.)

List[2] (p. 373.) Berthelot[3] (according to Oppenheim.) Tilden[5] (p. 249.)	By boiling the dihydrochloride with water.

Many of these references must be taben with considerable reserve. In most cases no pure terpineol was obtained. However, it is to be assumed that in all cases more or less of it was formed.

[33] According to Tilden [5] (p. 289) lemon oil contains 10–15 p. c. of a substance which has the same boiling point with terpineol and yields a dichloride melting at 48°. This "natural terpinol" is stated to be dextrogyrate. So called "Cajeputol" is stated to contain a fraction which boils above 200°, which is capable of yielding a dichloride melting at 48°.

Weber (Annalen, Bd. 238, p. 101) separated from cardamom oil a fraction 205–220°, which yielded dipentene dihydrochloride, melting at 52°. He did not succeed in making the carbanil reaction.

Watts (J. C. S. vol. 49, p. 316) has sufficient faith in an insignificant color reaction to conclude from it the presence of terpineol in the oil from the leaves of Citrus Limetta.

Bertram and Gildemeister (Archiv d. Pharm. Bd. 228, 485), assume the presence of terpineol beside borneol in the fraction 200–220° of kesso-oil (valeriana officinalis, var. angustifolia.) They obtained from this fraction dipentene dihydriodide melting at 76°. The oil also contains dipentene.

Kwasnick (Berichte, Bd. 24, p. 81) reports as follows of a fraction from Kuro-moji-oil (Lindera fericia, Bl.): "Eine angenehm nach Fliederbluehten riechende Fluessigkeit $C_{10} H_{18} O$, siedet bei 218° und wurde durch sein Verhalten gegen Chlorwassertoff und gegen Brom, sowie durch sein schoen hrystallisirendes Jodid, welches bei 75–76° schmilzt, identificirt." This oil also contains + limonene, dipentene and — carvol.

ad Nitrosochlorides, etc.

[1] J. C. S. (1877), Vol. 31, p. 558.

[2] Annalen, Bd. 245, p. 245.

[3] J. C. S. (1875) p. 514 and ibidem (1877), p. 554.

[4] J. C. S. 1864.

[5] Berichte, Bd. 18, pp. 1729 and 2220.

[6] Annalen, Bd. 245, p. 241.

[7] Ibidem, Bd. 252, p. 108.

[8] Ibidem, p. 109; Comp. also ibidem, Bd. 245, p. 255, and Dissertation, p. 18.

[9] Ibidem, Bd. 252, p. 111; also "Wissenschaftliche Beilage zum Jahresbericht des Elizabeth Gymnasiums, Breslau, Ostern '90.

[10] Ibidem ,p. 124.

[11] Dissertation, p. 22.

[12] Annalen, Bd. 252, p. 125.

[13] Annalen, Bd. 252, p. 145.

[14] Ibidem, p.112.

[15] Dissertation, p. 23.

[16] Annalen, Bd. 252, p. 146.

[17] Dissertation, p. 24.

[18] Annalen, Bd. 245. p 256.

[19] Ibidem, Bd. 245, p. 257, and
Ibidem, Bd. 246, p. 224.

[20] Ibidem, Bd. 245, p. 268, and
Ibidem, Bd. 246, p. 227.

[21] Ibidem, Bd. 245, p. 257.

[22] Ibidem, Bd. 252, pp. 111 and 125, also
Dissertation, p. 24, et. seq.

[23] Annalen, Bd. 245, p. 258.

[24] Ibidem, p. 270.

[25] Wallach, "Nitrosate and Nitrosite" etc., Annalen, Bd. 241, p. 288.
Wallach, Sechste Abhandlung Ibidem, p. 315.
Wallach, Siebente Abhandlung Ibidem, Bd. 245, p. 241.
Wallach, Elfte Abhandlung Ibidem, Bd. 252, p. 106.
Kremers, Dissertation.

[26] Annalen, Bd. 245, p. 271.
Ibidem, Bd. 252, pp. 113, 125 and 146.

[27] Ibidem, pp. 121, 126 and 147.

[28] Ibidem, pp. 118 and 126, also.
Dissertation, pp. 24 and 60.

[29] Dissertation, p. 29.

[30] Dissertation, p. 34.

[31] Annalen, Bd. 245, p. 260.
Dissertation, p. 46.

[32] Annalen, Bd. 245, p. 260.
Dissertation, p. 49.

[33] Annalen, Bd. 245, p. 265.

[34] Dissertation, p. 51.

[35] Annalen, Bd. 245, p. 262.
Dissertation, pp. 55 and 34.

[36] Ibidem, p. 60.

THE PSEUDO-GREGORIAN DRAMA *Χρίστος Πάσχων* IN ITS RELATION TO THE TEXT OF EURIPIDES.

BY F. L. VAN CLEEF, PH. D.

PART I.—THE BACCHAE.

The Christian Drama *Χρίστος Πάσχων*, which by its superscription is ascribed to Gregorius Nazianzenus, has been clearly shown by Dœring and Brambs not to be in accord with the other writings of Gregorius and assignable not to him but to a much later writer. Dœring[1] attributed it to Tzetzes but Brambs,[2] who has most recently and most thoroughly studied the problem, assigns it with seemingly greater right to Theodorus Prodromus or an author of that period, i. e. of the 11th or 12th century.

The drama is a cento constructed of lines taken from the Prometheus and Agamemnon of Aeschylus, the Cassandra of Lycophron, the Holy Scriptures including Genesis, Exodus, the Psalms, the four Gospels, the letters of Paul and even the Apocryphal books; but mainly, as the writer acknowledges in his introduction (v. 3 sq.), from Euripides, of whom he has used seven plays known to us, Hecuba, Orestes, Medea, Hippolytus, Troades, Rhesus and Bacchae. From these plays it is evident that the MS. of Euripides, that the writer had in his possession, must have been the second of the two classes, into which Kirchhoff has divided our existing MSS. of Euripides, and that no more plays were used may be accounted for on the supposition that the MS. used by the writer contained only the seven above-mentioned plays, with which were perhaps bound the two mentioned plays of Aeschylus and the Cassandra of Lycophron. That the writer had no other plays of Euripides before him seems certain from the fact that he has plundered these in a most thorough manner, not con-

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[1] De tragoedia Christiana quae inscribitur *Χρίστος Πάσχων*, Realschulprog. Barmen, 1864, p. 8.

[2] De auctoritate tragoediae Christianae quae inscribi solet *Χρίστος Πάσχων* Gregorio Nazianzeno falso attributae. Diss. inaug. scripsit J. G. Brambs, Eichstadii, 1883, p. 64. Cf. also the Praefatio of Brambs' edition of the Christus Patiens, Teubner, 1885, p. 17 sqq.

tent to take here and there a line. Everything that could be of service has been utilized and the remarkable thing is that he was not tempted to use the same line twice. Indeed he seems to have checked off each line as fast as used and never to have repeated it without considerable variation. Nor has he taken the verses in their original order but we find brought together in the same speech verses not only of different speakers but taken from very different portions of the same play. Thus of the prologue of the Medea verses 20–39 (excepting only 23, 24 and 29) have been used by the writer of the *Χρίστος Πάσχων* as follows: V. 20 = 4 of the *Χρ. Π.*; 21 sq. = 51 sq.; 25 sq. = 46 sq.; 27 sq. = 972 sq.; 30 = 974; 31 sq. = 945 sq.; 33 = 949; 34 — 36 = 53 —55; 37 = 489; 38 = 485; 39 = 491. From this it is plain that he was so thoroughly master of these sixteen verses that he has interspersed them in one thousand lines of his drama.

Inasmuch as we have here excerpts from plays of Euripides preserved in some cases in a single manuscript and in others in only two, it would seem probable at first consideration that this cento would be of great value in determining the text of Euripides. This question was early investigated, soon after the appearance of Kirchhoff's critical edition of Euripides, by A. Dœring.[1] Kirchhoff had previously pointed out the fact that the MS. of Euripides used by the author of this cento contained without doubt the portion of the Bacchæ after v. 1328, which our present MS. lacks, and hence was derived from an archetype which contained the whole of that play.[2] But Dœring, after citing all those passages in which the *Χρ. Π.* had preserved, as he judged, the real reading of Euripides, reached the conclusion that the MS. used by the author of the *Χρ. Π.* was inferior to the MSS. of Class I but superior to those of Class II of the Euripidean MSS. It is my intention in this paper to investigate the problem more thoroughly and to set forth clearly both sides of the shield, inasmuch as there was a feeling that but one side had been clearly shown in the articles of Dœring in Philologus. And that the paper may not be too colossal in its magnitude, it has been decided to limit the present investigation to one play of Euripides, the Bacchæ, preserved in only two MSS., a Palatinus 287 of the 14th century (designated by the letter P.) and a Florentinus XXXII (known by the designation C.) also of the 14th century which, however, contains but the first half of the play, lacking all from verse 756 on to the end (1392). As the writer of the *Χρ. Π.* has taken from the 1392 lines of the Bacchæ (the extracts from those portions now lost in our MSS. do not come here into consideration) over 250 lines for his cento, over half of which are from

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[1] Die Bedeutung des Tragœdie *Χρ. Π.* für die Textkritik des Rhesus, Philologus 23 (1866), pp. 577–591, and Die Bedeutung der Tragœdie *Χρ. Π.* für die Euripidestextkritik, Philologus 25 (1868), pp. 221–258.

[2] Ein Supplement zu Euripides' Bakchen, Philologus 8 (1853), pp. 78–93.

the latter half of the play, preserved in a single MS. of the 14th century, there would seem to be good opportunity in this play for determining the value of the citations as found in the *Χρ. Π.* for the text of the Bacchæ.

It must first be remarked that, as the subject of the cento did not often allow its author to quote directly without change from his chosen model, we expect to find many variations from Euripides occasioned by this fact, and do not expect to find many lines to be taken *verbatim* Bearing this in mind three classes of citations as made by the author of the *Χρ. Π.* may be distinguished.

I. Those verses in which one or more words have been necessarily changed to bring into harmony with the theme the heathen conceptions of Euripides. This class also includes all those verses in which by reason of the context some change has been made. The verses in this class must necessarily constitute the great majority of all the verses quoted and we add here the list that it may be of service to any who may desire to investigate the question further.[1]

1 = *Χρ. Π.* 1573 (?)
2 = 1545 (?)
4 = 1546, 1533, 1535 sq., 1543, 1758 sq., 2395, 2405, 2574[2]
7 = 1582
10 = 1585
11 = 1586
21 = 1563[3]
26 = 1547
27 = 1550
28 = 1551
29 = 1553
30 = 1555
31 = 1552 (?)
40 = 1568
47 = 1574, 1564
48 = 1565
50 = 1575
51 = 1576
52 = 1577, 1536, 1543
53 = 1512, 2374
54 = 1536, 1543
58 = 1606, 1124
60 = 2519
61 = 2520
69 = 1608
71 = 1607
72 sq. = 1139
73 sq. = 1140
75 sqq. = 1141
80 sqq. = 1142, 1144
120 = 1599
179 = 1149
180 = 1150
181 = 1152

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[1] The first and only complete list of quoted verses that exists is to be found in the preface of Brambs' edition in the Teubner series, p. 8 sqq. The list of verses quoted from the Bacchæ (p. 15 sqq.) is almost complete. I have added but two further citations. In a considerable number of instances the parallelism as there referred to is so very remote as to be of no value for our investigation, and to leave great doubt in the mind if the verse is really modeled after that of Euripides.

[2] When more than one verse of the *Χρ. Π.* is cited as a parallel of a verse from the Bacchae, the one that stands first is the real corresponding verse, the others may be neglected, as corresponding only vaguely with the given line.

[3] The proposal to read here the future participles *χορεύσων καὶ καταστήσων* from the evidence of the *Χρ. Π.* is neither consonant with the context, nor demanded by the *Χρ. Π.* For it is not true that the tense has never been changed in the *Χρ. Π.* Such a change occurs in 280 = 571; 1120 = 2564; 1128 = 1162; 1237 = 163; 713 = 2218; 213 = 1561; 777 = 2245; 955 = 1506; 1077 = 2254; 1223 = 2202.

183 = 1153
186 = 1156
187 = 1157
213 = 1561
231 = 1558
232 = 1559, 1557[1]
240 = 1557[2]
248 = 1136
264 = 193
265 = 194 sq.
280 = 571
283 = 570
287 = 572
288 = 575
289 = 577, 585
290 = 579
291 = 580
306 = 587
307 = 588
309 = 584
313 = 586
315 = 263[3]
333 = 599, 565
335 = 1032, 565, 599
360 = 1788
361 = 1789
362 = 1790
363 = 1791
389 sq. = 1801
390 = 1803
391 = 1804
442 = 1384 (?)
443 = 1385, 1928
445 = 2070, 2073
446 = 2074
447 = 2075
450 = 1655
489 = 1556
492 = 1668
666 = 2212
670 = 2222
678 = 1845
683 = 1833
684 = 1835
685 sq. = 1836
693 = 2018
712 = 2216
732 = 1812, 1810
733 = 1811, 2039
760 = 1101 (?)
761 = 1102 (?)
769 = 2262
770 = 2263
772 = 2265
774 = 2266
775 = 2221
777 = 2245
779 = 2228
780 = 2229
788 = 2278
789 = 2279
790 = 2280
846 = 2287
854 = 2311
960 = 1522
962 = 1524
963 = 1525
964 = 1526
967 = 1521
972 = 1531
973 = 1306, 1295
995 (= 1015) = 1437
1025 = 1648
1026 = 1649 sq.[4]
1027 = 647, 1601
1030 = 438, 654
1031 = 1535, 2100, 2542
1032 = 652, 2192
1043 = 657
1044 = 658
1046 = 675
1050 = 678
1064 = 660
1065 = 661
1068 = 663
1069 = 566
1073 = 662
1077 = 2254
1079 = 2257
1082 = 2258
1085 = 2261
1086 = 671, 2013
1088 = 170, 2016
1089 = 2017, 171
1095 = 666
1097 = 668
1113 = 1432
1118 = 2566
1128 = 1162
1135 = 1473
1143 = 1167
1144 = 1062
1202 = 1598
1214 = 1264
1215 = 1265

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[1] The change of *παύσω* to *στήσεις* is doubtless due to the fact that the author of the *Χρ. Π.* had already used *παύσεις* in 1557. After substituting *κακουργίας* for *τῆσδε βακχείας* he could scarcely retain *κακούργου* and hence changed it to *κακοῦργον*.

[2] This similarity has been overlooked by Brambs.

[3] The dative of the *Χρ. Π.* is partial testimony to the dative of C., P., and Stob. 5, 15. Stobaeus 74, 8 reads *εἰς τὴν φύσιν*.

[4] *ἐν γῇ* of the *Χρ. Π.* testifies somewhat to *ἐν γαίᾳ* of P. and against Wecklein's emendation, *ἐν γυίαις*.

1217 = 1486
1219 = 1487
1221 = 1488
1226 = 1455
1233 = 161
1239 = 165
1240 = 166
1243 = 169
1259 = 1053
1260 = 1890
1262 = 1056, 1892
1263 = 1058
1280 = 1310, 444, 853
1281 = 854
1314 = 1342
1315 = 1343
1327 = 1712 sq.
1328 = 1714
1332 = 1760
1333 = 1680
1335 = 1683, 1678
1336 = 1678
1337 = 1681
1338 = 1752, 1682
1339 = 2573
1340 = 1685
1346 = 2562
1352 = 1700
1353 = 1701
1356 = 1671, 1758
1360 = 1684, 1695
1362 = 1697
1366 = 1703
1368 = 1706
1369 = 1706 sq., 1669, 1756.

II. The second class of citations consists of those verses which are quoted exactly as we have them in our existing Euripidean MSS. This list is even larger than we should have expected and embraces fifteen lines, the enumeration of which is here given:

Bacchæ. *Χρ. Π.*

Found in both P. & C.
39 = 1567
178 = 1148
316[1] = 264
668[2] = 2219
669[3] = 2220
679 = 1846

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[1] This verse which stood clearly in the Eur. MS. of the author of the *Χρ. Π.* at this place, as in the two MSS. of the Bacchae, (for *Χρ. Π.* 314 — 316 = Bacch. 262 — 264) is rejected by Kirchhoff and Wecklein, (Cf. the latter's Curae Criticae, p. 18. Wecklein considers it a dittograph of Hipp. 79.) because it was lacking in Stobaeus 74.8, who quotes the whole passage. Nauck, on the other hand, following Dindorf, rejects Hipp. 79–80 as spurious, and retains our verse. If the verse is to be rejected, then the MS. used by the author of the *Χρ. Π.* is in no way superior to our Euripidean MSS. and the interpolation must have been made in the common archetype of our MSS. and that in the possession of the author of the *Χρ. Π.*

[2] MS. A. of the *Χρ. Π.* reads πότερ' ὡς, V. πώτερον (omitting σοι). Caillau's Benedictine edition of 1840 (*Χρ. Π.* appended to the works of Gregorius Naz.) πρῶτον σοι. This variance we shall have occasion to mention later.

[3] Here the *Χρ. Π.* agrees with our Euripidean codices in reading τἀκεῖθεν, which Brunck, whom all subsequent editors have followed, changed to τὰ κεῖθεν.

Found in P. alone
771 = 2264
794[1] = 2268
795 = 2269
838 = 1930
1078 = 2256
1112 = 1431
1152[2] = 1147
1261[3] = 1055
1361 = 1696

III. So far we have made no distinction between the MS. of Eur. used by the author of the *Χρ. Π.* and the existing MSS. of the Bacchæ. It is in the third class of citations that we shall have occasion to see of how much value the citations from Euripides found in the *Χρ. Π.* are. This class includes all those verses in which no particular reason seems to exist to justify a change, and yet, which show some variation from the MS. readings of the Bacchæ. Here three sub-divisions are to be distinguished. A. those cases in which the *Χρ. Π.* presents a reading so plainly superior to our MSS. reading that it has been adopted by Kirchhoff and all who have followed him: B. those cases in which the *Χρ. Π.* offers a reading which has appeared to some of the editors of Euripides worthy of adoption or in which the readings presented by the *Χρ. Π.* seem at least equally good with those of the MSS.: C. those cases in which the *Χρ. Π.* presents a corrupt reading, although there is no apparent reason to justify the corruption.

A. The verses in which the readings of the *Χρ. Π.* have been adopted by all the editors of Euripides in preference to those of our Euripidean MSS. are the following:

1. 55. C. & P. *λιποῦσα*, *λιποῦσαι* C² as also *Χρ. Π.* 1602, Et. M. 453 C., while Strabo, 469, testifies at least to the ending —*αι*. [Here as in a number of other cases the testimony of the *Χρ. Π.* is entirely ignored by Kirchhoff.]
2. 655. P. & C. read *σοφὸς σοφὸς εἶ*. But the *Χρ. Π.* 1529, *σοφὸς σοφὸς σύ*.
3. 694. P. & C. read *παρθένοι τε κἄζυγες*. The *Χρ. Π.* on the other hand has *παρθένοι τ' ἔτ' ἄζυγες* which all have adopted. Usener's conjecture, (Rh. Mus. XXIII. 160) *σύζοι τε*

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[1] MSS. V. and B. of the *Χρ. Π.* *αὐτὸν*.

[2] MS. P. and the *Χρ. Π.* read *χρῆμα*. Orion, Anth. 4, p. 55, reads *κτῆμα*, which all the editors have adopted. (Nauck adopts without any note of the change!) Here again, if the MS. of Euripides is wrong, the *Χρ. Π.* is wrong with it, and the corruption is to be traced to the archetype of P. and the Euripidean MS. of the *Χρ. Π.*

[3] Bruhn proposes for *μένειτ' μενοῖτ'* against the combined testimony of P. and the *Χρ. Π.*

κἄζυγες, seems extremely probable, in which case the Euripidean MSS. have preserved the reading better than the *Χρ. Π.*, although both have been corrupted by the in corporation of the gloss, *παρθένοι*, into the text.

The remainder of the cases are from the portion of the play preserved only in codex P.

4. 778. P. reads *ἐφάπτεται.* But the *Χρ. Π.* 2227 *ὑφάπτεται.* (But codex V. of the *Χρ. Π.* shows the same corruption *ἐφάπτεται.*)
5. 1031. *σύ* om. codex. But the *Χρ. Π.* 2100 and 2542 retains *σύ*, though the order of the words is changed. Kirchhoff is followed in the insertion of *σύ* by Nauck and Bruhn. Other editors have suggested other methods of restoring either the dochmiacs or a trimeter. At the best the reading of the *Χρ. Π.* cannot be regarded as very much superior to that of the Palatinus.
6. 1041. P. *τίνει.* But *Χρ. Π.* 653 *τίνι.*
7. 1049. P. *ἐκποδῶν. Χρ. Π.* 677 *ἐκ ποδῶν.*
8. 1096. P. *κραταβόλους. Χρ. Π.* 667 *κραταιβόλους.*
9. 1151. P. *οἶμαι γ'. Χρ. Π.* 1146 and Orion, Anth. 4, 55 *οἶμαι δ'.* [Here again K. ignores the additional testimony of the *Χρ. Π.*] Reiske changed to *ταὐτὸ*, which Paley follows.
10. 1161. P. *ἐξεπράξατο. Χρ. Π.* 1050 *ἐξεπράξετε.* Scaliger had suggested the change, to whom K. and W. ascribe the reading.
11. 1344. P. *λισσόμεθα.* Codex V. of *Χρ. Π.* 2557 *λισσόμεσθα*, the remaining codices agree with the Palatinus. Musurus changed to *λισσόμεσθα*, to whom the emendation is ascribed by K. and W. with no reference to the *Χρ. Π.*
12. 182. This verse seems rightly rejected here, as Dobree has done, not only because it is a paraphase of 860 but because the *Χρ. Π.*, which quotes the whole passage from 178 to 187 in verses 1148–1157, entirely ignores the existence of this verse. Evidently it was not to be found in his MS. of the Bacchae, else he had made use of it for his theme.
13. 1213. P. *πλεκτῶν. Χρ. Π.* 1263 *πηκτὰς*, from which Barnes drew the emendation *πηκτῶν.* The passage will be treated again.
14. 1345. P. *ἐμέθεθ'* which Musurus corrected to *ἐμάθεθ'.* The mistake is not to be found in *Χρ. Π.* 2560, where the form given is *ἐμάθομεν.*

B. Verses in which the reading presented by the *Χρ. Π.* seems at least as good as that of our MSS. of the Bacchae.

1. 1048. P. *πικρόν*, which Musurus emended to *ποιηρόν.* The *Χρ. Π.* 676 reads *χλοηρόν.* The passage is ably treated by Doering (Phil. XXV. (1867)). *ποιηρός* is found twice in

classical Greek and both occurences are in the Cyclops of Euripides, 45 and 61. χλοηρεῖ is the form in P. at Bacch. 106, χλοηρεῖ with *ου suprascr.* in C. Cf. Wilamowitz, Anal. Eur. p. 47. Hermann on this passage, reasoning from the analogy of κισσήρης, decided that χλοήρει was to be read here. For our passage we must assume a co-ordinate form χλοηρός, although it does not occur elsewhere. It were possible to read in the *Χρ. Π.* χλοήρες or χλοηρές to bring it into harmony with Bacch. 106. There was no reason why the author of *Χρ.Π.* should have made a change and he doubtless found χλοηρόν in his MS. of Euripides.

2. 1084. P. εὔλειμος. But *Χρ. Π.* 2260 ὕλιμος. εὔλειμος is a ἅπαξ λεγόμενον. ὕλιμος is said to be found in frag. 395. 34. Cf. Wilamowitz on this line in Bruhn's edition of the Bacchae.[1] And Doering rightly notes (Phil. XXV. (1867)) that ὕλιμος agrees better with φύλλ' ειχε of 1085 and strengthens the idea of σῖγα, while εὔλειμος seems an unnecessary epithet of the νάπη. Εὔλειμος could easily have arisen from ὕλιμος by reason of the pronunciation. Inasmuch as ὕλιμος is rightly constructed (cf. χρήσιμος, δόκιμος, etc.), occurs elsewhere (?) and suits the context better, while εὔλειμος is as least somewhat suspicious in its formation, Bruhn inserts the former in the text, while Wecklein decides also in its favor.
3. 1353. The line in P. has only five feet. The probable completion of the line, πάντες, was suggested by Kirchhoff from *Χρ. Π.* 1701 πάντας. This emendation has been adopted by Schoene and Bruhn. Other editors have proposed other solutions of the difficulty, while Paley desired to reject the verse entirely. πάντες seems the simplest emendation and the only one that has the slightest authority.
4. 787. P. reads λόγων κλύων. But the *Χρ. Π.* 2277 κλύειν λόγων. Nauck preferred to change to κλύων λόγων. The use of the infinitive in the *Χρ. Π.* seems justified by the difference in meaning, as Doering (Phil. XXV.) has shown, but the transposition can be due only to one of two causes. 1. Because the author of the *Χρ. Π.* found the words in their transposed order in his MS. of Euripides; or 2. Because

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[1] I have been unable to find the citation. On careful inspection of the references to the fragments of Euripides in Bruhn's edition of the Bacchae it is not at all evident what edition he made use of, as the numbers correspond in no instance with the editions within my reach, viz. the older collections of Matthiae and Dindorf and the editions of Wagner and Nauck.

he made an arbitrary change in the Euripidean text. The latter seems to be the reason in this case. As the next line in the *Χρ. Π.* ends with *κλύων*, its author apparently desired to avoid the simularity of endings and so changed the order of words in this line. There seems to be no reason for preferring with Nauck the reading *κλύων λόγων*.

5. 14. The line is lacking in C. P. and Strabo I. 27 and XV. 687 read *Περσῶν θ'*, which Elmsley wished to emend to *δ'* and Wecklein, who in 16 reads *ἐπῆλθον* for *ἐπελθών* from Strabo XV. 687 (although Str. I. 27 gives *ἐπελθών*), drops *θ'* altogether. Wecklein however says nothing of the testimony of the *Χρ. Π.* 1588, which also omits *θ'* but preserves the participle in verse 16, though changed to *παρελθών*.
6. 20. P. and C. *πόλιν*. But *Χρ. Π.* 1595 *χθόνα* which Schenkl and Wecklein have taken into text, who also place verse 20 after 22. In the order of lines preserved by our MSS. the similar endings of 19 & 20, *πόλεις* and *πόλιν*, seem objectionable. But if the order be changed that objection is removed.

We may also include under this head those cases in which the citations from the *Χρ. Π.* agree with one of the MSS. and not with the other. They are as follows:

1. 75. P. *θιασσεύεται*. But C. and the *Χρ. Π.* 1141 *θιασεύεται*. This statement rests upon Bruhn's Kritischer Apparat. Wilamowitz in his Analecta Euripidea does not note this variance of the MSS., so that it seems at least questionable.
2. 46. P. *οὐδαμοῦ* with which the *Χρ. Π.* 1571 agrees. C. *οὐδαμῶς*.
3. 56. P. *ξυνεμπόρους*. C. and the *Χρ. Π.* 1603 *συνεμπόρους*. All editors follow MS. P.[1]
4. 314. P² with Stobaeus Flor. 5.15 and 74.8 read *μὴ σωφρονεῖν*. P. C. and the *Χρ. Π.* 262 *σωφρονεῖν* without *μή*.

In the following passage the thought rather than the word of the *Χρ. Π.* has furnished Hartung (whom Schoene & Bruhn have followed) with a plausible correction of MS. P. 1090–1 *ἥσσονες* || * *ἔχουσαι* certainly cannot stand. Kirchhoff, following Heath, reads for *ἥσσονες ἥσσονα* and retains *ἔχουσαι*. Wecklein prefers to bracket 1091. The three

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[1] In 443 = *Χρ. Π.* 1385 and 1928 the MSS. of Euripides read *ἃς, συνήρπασας*: *Χρ. Π.* 1385 *οὓς συν-* but 1928 *οὓς ξυν-* Such a point is entirely beyond the evidence of late MSS., as seems also the case under consideration. It is only given to give the benefit of the doubt to the *Χρ. Π.* A similar question is that of *ἐς* and *εἰς*. Cf. 450 = *Χρ. Π.* 1655; 1073 = 662. Likewise *-η* or *-ει* in second person singular middle of the verb. Cf. 787 = 2277 and 2286; 960 = 1522. So also the *ι* subscriptum in the verb *σῴζω*; cf. 1050 = 678: and the accent of *σῖγα*; cf. 1084 = 2260.

above-mentioned editors draw from the signification of δράμωσι of the *Χρ. Π.* 2015 and the form of the reading of P. the emendation τρέχουσαι.

C. So far we have regarded the readings afforded us in any way by the *Χρ. Π.* as either superior or equal in value to those of our MSS. of the Bacchae. In Class C. will be collected all those passages in which the author of the *Χρ. Π.* has apparently with the utmost arbitrariness changed the Euripidean text or with a more charitable supposition found in his MS. a very corrupted form of the Euripidean text.

1. 8. *Χρ. Π.* 1583 has τεφρούμεν' for τυφόμενα and ἄσβεστον for ἔτι ζῶσαν. These changes were doubtless made to avoid the resolved feet. The Euripidean line is unmetrical and difficult. Barnes emended by dropping τε and he has been followed by all the editors but the line is not relieved of all its difficulties.
2. 9. *Χρ. Π.* 1584 πρὸς τήνδ' for εἰς ἐμήν. The same variation is found in
3. 312. *Χρ. Π.* 584 πρὸς γῆν for εἰς γῆν and
4. 776. *Χρ. Π.* twice (2244 and 2222) πρὸς τὸν τύραννον for εἰς τὸν τύραννον. Of these three cases the first may have been due to the context. To obtain a final long syllable in πόλιν, πρὸς may have been written after it instead of εἰς. But this explanation will not hold for the other two instances and the author of the *Χρ. Π.* does not elsewhere show such attention to the laws of quantity. A short ι lengthened under the influence of the accent is not a rare phenomenon in the *Χρ. Π.*
5. 13. *Χρ. Π.* 1587 πανευκλεεῖς πόλεις for πολυχρύσους γύας. The reading of the *Χρ. Π.* is testimony to the accusative. Elmsley, followed by Wecklein, reads πολυχρύσων.
6. 16. *Χρ. Π.* 1590 παρελθὼν for ἐπελθὼν. Here also 'Αρράβων for 'Αραβίαν to avoid the resolved foot. ἐπελθών is the reading of Str. I. 27, but Str. XV. 687 gives ἐπῆλθον, which Wecklein has adopted.
7. 22. *Χρ. Π.* 1564 ἐμφανῶς for ἐμφανὴς. Similar is
8. 993 = 1013. *Χρ. Π.* 1099 φανερῶς for φανερὸς.
9. 46. *Χρ. Π.* 1571 δ' for τ'.
10. 56. *Χρ. Π.* 1603 ἐμὸς θίασος for θίασος ἐμὸς.
11. 116 sq. *Χρ. Π.* 1614 ἐν ᾧ θηλυγενὲς μένει γένος for ἔνθα μένει ‖ θηλυγενὴς ὄχλος.
12. 184. *Χρ. Π.* 1154 χρῆ for δεῖ. But δεῖ is the emendation of Musurus for δὴ of the MSS., which corruption had its origin doubtless in itacism.
13. 185. *Χρ. Π.* 1155 νῦν ἡγοῦ for ἐξηγοῦ.

14. 194. *Χρ. Π.* 1161 *ἀπόνως* for *ἀμόχθει*. This is plainly a change as the line is unmetrically constructed. Codex Vindob. (V.) gives *θ' ἀπόνως ἡμῶν ἡγήσαιτο*. A. and B. *ἡμῶν ἀπόνως ἡγήσεται*. The remaining *ὑμῶν ἀπόνως ἡγήσεται*.

15. 211. *Χρ. Π.* 228 *κἀγὼ* for *ἐγώ*. Elsewhere the author of the *Χρ. Π.* has not been so particular about avoiding asyndeton.

16. 285. *Χρ. Π.* 569 *τοῦτο* V. B. D., ceteri *τούτου* for *τοῦτον*.

17. 444. *Χρ. Π.* 1386, 1929 *κἄδδησεν* for *κἄδησας*.

18. 448. *Χρ. Π.* 2072 *ἀνεῖσαν* for *ἀνῆκαν*.

19. 449. *Χρ. Π.* 1654 *θ'* for *δ'*. But V. reads *δ'*. Herwerden emended to *γ'*. Also *ἀνὴρ* for *ἁνήρ*.

20. 472. *Χρ. Π.* 1549 *βροτοῖς* for *βροτῶν*.

21. 667 = 716. *Χρ. Π.* 2213 *δ'* for *τε* (667) or *τ'* (716).

22. 671. *Χρ. Π.* 2223 *τὸ τ' ὀξύθυμον* for *καὶ τοὐξύθυμον*.

23-24. 672. *Χρ. Π.* 2233 *πάντων* for *πάντως* and also *δί' ἐμοῦ* for *ἐξ ἐμοῦ*.

25. 713. *Χρ. Π.* 2218 *εἰσορῶν* for *εἰσιδὼν*.

26. 955. *Χρ. Π.* 1506 *κρύψει σὺ* for *κρύπτῃ δὲ*.

27. 1029. *Χρ. Π.* 649 *τί μηνύεις* for *τι μηνύεις*.

28. 1083. *Χρ. Π.* 2259 *ἐστήριξε* for *ἐστήριζε*. In the *Χρ. Π.* the verbs of the lines immediately preceeding and following are in the aorist. That may account for the change in this line. In Euripides the verb in 1082 is imperfect, in 1084 aorist.

29. 1087. *Χρ. Π.* 673 *κάρας* for *κόρας*.

30. 1091. *Χρ. Π.* 2015 *ὁρμήμασιν* for *δρομήμασι*. This may be due to the fact that *δράμωσι* already stands in the line in the *Χρ. Π.*

31–32. 1111. *Χρ. Π.* 1430 *θᾶσσον* for *θάσσων*. For the use of the adverb for the adjective in such expressions cf. examples 7 and 8 supra. Also *χαμαιριφὴς* for *χαμαιπετής*. MSS. A. and B. of the *Χρ. Π.* read *χαμαὶ ῥιφῆς*.

33. 1120. *Χρ. Π.* 2564 *οἴκτειρον* for *οἴκτειρε δ'*.

34. 1121. *Χρ. Π.* 2565 *ἀμπλακίαισιν* for *ἁμαρτίαισιν*.

35. 1147. *Χρ. Π.* 1300 *ὡς καλλίνικος, ἢ κλέος νίκης μέγα*. A. and B. have *εἰ*, with *ἢ* written above it in B. *εἲ* V. C. M. *ὅπου ἢ*, where *ὅπου* is plainly a gloss upon *ἢ*. P. of the Bacchæ reads: *καλλίνικον ἢ δάκρυα νικηφορεῖ*, which Kirchoff, Paley and Nauck retain. Reiske, followed by Hermann and Bruhn, reads *ὦ*, while Heath emends to *ἦ*, the reading adopted by Schœne and Wecklein. Emendations of *νικηφορεῖ*, which is a *ἅπαξ λεγ.*, have been suggested by Portus, *νίκῃ φορεῖ*, and Hartung, *νίκη φέρει*, the latter two adducing the line in the *Χρ. Π.* as partial evidence. In any case the

author of the *Xρ. Π.* has changed to all appearances his Euripides.

36. 1150. *Xρ. Π.* 1145 γὰρ for δὲ.
37. 1163. *Xρ. Π.* 1052 αἵμασι for αἵματι.
38. 1213. *Xρ. Π.* 1263 ἔμβαινε πηκτὰς κλίμακος πρὸς ἐμβάσεις for πλεκτῶν πρὸς οἴκους κλιμάκων προσαμβάσεις. The correction of πλεκτῶν to πηκτῶν has been spoken of on page 369. In this line πρὸς ἐμβάσεις is plainly a corruption of προσαμβάσεις, which word the author of the *Xρ. Π.* apparently did not understand. But the singular κλίμακος is either a variant reading or a deliberate change. The singular κλίμακος with προσαμβάσεις is found in Aesch. Sept. 466 and Eur. Phoen. 1173. More instructive is Phoen. 489, where πηκτῶν κλιμάκων προσαμβάσεις is read, the two passages being plainly imitations, the one of the other. This seems a strong argument against Doering's suggestion that "πηκτάς passt besser zu den Stufen oder Sprossen, als zu der Leiter."
39. 1216. *Xρ. Π.* 1485 φέρωμεν for φέροντες.
40. 1223. *Xρ. Π.* 2202 εἴσω μολὼν for ἔσω βεβὼς.
41. 1237. *Xρ. Π.* 163 ἥξω for ἥκω.
42. 1241. *Xρ. Π.* 167 κυδρούμενος for γαυρούμενος.
43. 1244. *Xρ. Π.* 1048 ὦ μέγεθος for ὦ πένθος. Here πένθος is restored by all the editors of the *Xρ. Π.* It is doubly strange that this corruption should have crept in, as it introduces a resolved foot, which, as we shall later see, the author of the *Xρ. Π.* plainly avoided. It seems probable that μέγεθος stood in his Euripidean MS.
44. 1245. *Xρ. Π.* 1049 ἐξειργασμένοι for ἐξειργασμένων. P. reads here ἐξειργασμένῶν. Probably the author of the *Xρ. Π.* did not understand the construction.
45. 1316. *Xρ. Π.* 1634 θανὼν ἐμοὶ δ' for γὰρ οὐκέτ' ἂν.
46. 1317. *Xρ. Π.* 1635 ἀεί γ' for ἔμοιγ'.
47. 1348. *Xρ. Π.* 2563 ὀργὰν for ὀργὰς.
48. 1354. *Xρ. Π.* 1702 κἀγὼ for ἐγώ θ'.

To this list should be added the cases in which, to avoid a resolved foot, a change has been made by the author of the *Xρ. Π.*, which number 22, and are catalogued on pp. 376 sq.

In the following instances neither our MSS. nor the *Xρ. Π.* has preserved the correct reading.

1. 15 = *Xρ. Π.* 1589. δύσχειμον, corrected by Elmsley to δύσχιμον· This is explained by itacism.
2. 263 = *Xρ. Π.* 191. P. and C. εὐσεβείας, which Reiske corrected

to *δυσσεβείας*, a reading adopted by all. The *Χρ. Π* reads *ἀσεβείας*, which gives the right sense but is unmetrical.

3. 669 = *Χρ. Π.* 2220. *τἀκεῖθεν*, corrected by Brunck to *τὰ κεῖθεν*, due to the incorrect division into words.
4. 844 = *Χρ. Π.* 1287. P. *εὐπρεπὲς* corrected by Canter to *εὐτρεπὲς*. The *Χρ. Π.* has *πανευπρεπὲς*.
5. 854 = *Χρ. Π.* 2311. *ὄφλειν*, connected to *ὀφλεῖν* for Euripides. Cf. L. and S. sub voce.
6. 955 = *Χρ. Π.* 1506. P. *κρυφῆναι*. *Χρ. Π.* *κρυβῆναι*. Musurus corrected to *κρυφθῆναι* for metrical reasons.
7. 1099 = *Χρ. Π.* 669 *ἄλλοι*, corrected by Brodaeus to *ἄλλαι*.
8. 1152 = *Χρ. Π.* 1147 *χρῆμα*. But Orion, Anth. IV. 55, reads *κτῆμα*, which all editors adopt.
9. 1162 = *Χρ. Π.* 1051. P. *γόνον*. *Χρ. Π.* *θρῆνον*. Canter changed to *γόον*. It is possible that the *Χρ. Π.* may be right here.
10. 1355 = *Χρ. Π.* 1670. P. *ἔτι δέ μοι τὸ θέσφατον*. *Χρ. Π.* *ἔστι γὰρ τὸ θέσφατον*. It seems likely that the author of the *Χρ. Π.* found in our Euripidean MS. what our MS. now contains, but changed to obtain a verb and to avoid the tribrach. Haupt suggested *μοὔστὶ*, which all the editors have adopted.
11. 1368 = *Χρ. Π.* 1706. *πατρῷα*, changed by Elmsley to *πατρία metri causa*.

It remains now to sum up our discussion of the value of the citations from Euripides found in the *Χρ. Π.* If we have correctly classified the citations the conclusion is evident. In 14 instances the *Χρ. Π.* has furnished us the means of correcting our MSS., of which three instances only are from that portion of the play contained in the two MSS. The *Χρ. Π.* has not preserved the exact form of the word in all cases, nor have all, or even the best MSS. of the *Χρ. Π.* preserved the correct reading in every case. The benefit of the doubt has been given the *Χρ. Π.*, so that cases 13 and 14 have here been included, and case 11, although testified to by only one MS., and that not the best one. In our second list are to be found 6 cases in which the excellence of the readings of the *Χρ. Π.* is by no means so clear as to recommend their adoption to all the editors of the Bacchæ. In four cases the *Χρ. Π.* stands in agreement with one MS. and not the other, in two of which there may be serious doubt, if the reading of the *Χρ. Π.* is preferable. However, to be perfectly fair and just to the *Χρ. Π.*, these cases may be all enumerated in its favor, and the sum total is 24, over against which should be placed the 48 + 22 = 70 cases in which the author of the *Χρ. Π.* has without any doubt and for no good reason changed the reading of the Euripidean text, or found a very corrupt form of the Euripidean text in his MS. In the following it will be shown that the writer of the *Χρ. Π.* was apparently exceedingly faithful to his Euripidean text, and changed it, in all probability, only to avoid having more than twelve syllables in his line, and that in consequence his text of the Bacchæ was of a most corrupt nature. If this is substantiated then it is difficult to place any reliance upon the evidence of the *Χρ. Π.*, so far as the text of the Bacchæ is concerned. If, then, this be the truth in the case of the Bacchæ, where the Euripidean MSS. are so poor, the testimony of the *Χρ. Π.* for plays contained in better MSS. will be proved to be almost unworthy of consideration.

That the author of the *Χρ. Π.* followed his text of Euripides faithfully, even slavishly, is evident from the following considerations:

1. The retention of the Doric forms of choral passages. Such are *βιοτάν* of 1140 = B. 73 and *ψυχάν* of 1141 = B. 75. In only one instance is this neglected. In 1801 *τῆς* is written, where Bacchæ 389 shows *τᾶς*, which change is easily explained as due to the effect of the added word *καλῆς*.

2. Line 1099 is very instructive as to the fidelity of the author of the *Χρ. Π.* to his Euripides and also of the liberty he allowed himself with the text. Bacch. 993 = 1013 reads, *ἴτω δίκα φανερός, ἴτω ξιφηφόρος*, a trimeter although in a choral passage. This contained a resolved foot, which was an offense to the writer of the *Χρ. Π.* His version is, therefore, *ἴτω δίκ', ἴτω φανερῶς ξιφηφόρος*, where he has preserved the Doricism *δίκα*, but treated the final vowel as short and subject to elision. He would certainly never have attempted to elide an *–η*, had he found that in his MS. of the Bacchæ, so that we may regard the Doric form preserved in this instance also.

3. In 1150 = B. 180, although the author of the *Χρ. Π.* has added to the sentence the three last words of 1149, while Euripides connected their equivalent with the preceding line and began a new sentence with this one, the *Χρ. Π.* shows the *δ'* retained from Euripides, although now the fifth word in its sentence.

In 1594 codex V. has preserved *ἔχουσα* (nom.), though the construction demands the accusative, and the other MSS. have the accusative, *ἔχουσα* being the form found in the Bacchæ 19. Perhaps this is to be regarded rather as an error of V. than as the retention of the Euripidean reading, although in several instances V. has preserved the better readings. Cf. Brambs' praefatio to his edition, p. 5.

4. The preservation of resolved feet. It has already been pointed out in several instances that the author of the *Χρ. Π.* has taken the liberty of changing the Euripidean text to avoid a resolved foot. It remains to be shown how far this influence has been at work in the *Χρ. Π.* Before giving the complete list of cases, a few deserve special mention, as being very instructive of the method taken by this writer. The simplest way to avoid a resolved foot was to omit a word from the line. This has taken

place in 168 = B. 1242 where *γάρ* has been dropped to obtain a twelve syllabled verse: *καλει φίλους εἰς δαῖτα· μακάριος εἶ* for *μακάριος γὰρ εἶ*, in which the first *α* and the *ι* of *μακάριος* receive the accent, although short in quantity. Again 1589 = B. 15. Here *τε* has been dropped, thus *Βάκτρια* [*τε*] *τείχη τὴν τε δύσχειμον χθόνα*, where *ι* of *Βάκτρια* receives the accent.

A second way to avoid the tribrach was to combine with the omission or elision of a syllable transposition. Thus 2007 = B. 692. *αἶδ' ἀποβαλοῦσαι τὸν ὕπνον ὀμμάτων* from *αἳ δ' ἀποβαλοῦσαι θαλερὸν ὀμμάτων ὕπνον*. Here are three violations of the rules for quantity, in the two *α*'s of *ἀποβαλοῦσαι* and the *υ* of *ὕπνον*. In 1099 the remarkable elision of Doric *α* has been noted on p. 376. In 1592 = B. 17, the *Χρ. Π.* reads *πᾶσαν τ' Ἀσίαν κτλ.* for *Ἀσίαν τε πᾶσαν κτλ.*

Then again a change of words could be made. Thus 2223 = B. 671 *τὸ τ' ὀξύθυμον καὶ τὸ λίαν ἡρμένον* for *καὶ τοὐξυθυμον καὶ τὸ βασιλικὸν λίαν*, where *ι* of *λίαν* is lengthened. And 1566 = B. 49. *εὖ διαθεὶς τἀνθένδ', ἀναστήσεις κράτος* for *τἀνθένδε θέμενος εὖ, μεταστήσω πόδα.* An interesting example is 1054 = B. 1260 *εἰ δ' ἕως τέλους* for *εἰ δὲ διὰ τέλους*.

These cases will suffice for illustration. The remainder are: 569 = B. 285; 1310 = B. 1280; 1536 and 1543 = B. 54; 1564 = B. 22; 1570 = B. 45; 1583 = B. 8; 1590 = B. 16; 1593 = B. 18; 1603 = B. 56; 1683 = B. 1335; 1754 = B. 1339; 2075 = B. 447; 2519 = B. 60; 2560 = B. 1345. In most of these cases short vowels have been lengthened to receive the accent· Adaptation of lines written in other metres are full of the same sort of errors. Cf. 653 = B. 1041; 1052 = B. 1163; 1706 = B. 1368.

Further when the author of the *Χρ. Π.* found it necessary for his theme to change the Euripidian text, he avoided the use of a resolved foot, where the Euripidean equivalent has such. The following are the instances: 169 = B. 1243; 666 = B. 1095; 668 = B. 1097; 1152 = B. 181; 1153 = B. 183; 1156 = B. 186; 1161 = B. 194; 1525 = B. 963; 1552 = B. 31; 1553 = B. 29; 1602 = B. 55; 1668 = B. 492; 1760 = B. 1332; 1790 = B. 362; 1811 = B. 733; 1835 = B. 684; 2074 = B. 446; 2280 = B. 790; 2520 = B. 61. In many of these cases a short *α* is lengthened under the influence of the accent.

But to return to our point. In four instances the author of the *Χρ. Π.* has retained unwittingly, it would seem, a resolved foot, indicating how carefully he followed his Euripidean MS. When off his guard he followed his model and allowed a line to him metrically objectionable to creep in in its exact form. When he has tried to remove the source of objection he has betrayed himself by his absolute ignorance and disregard of the laws of quantity. The instances referred to are as follows: 1585 = B. 10. Here the MSS. C., M., A., B. read with Euripides *αἰνῶ δὲ κρίσιν* [Eur. *Κάδμον*] *ἄβατον ἣ* [Eur. *ἃς*] *πέδον τόδε.* Both Dübner and

Brambs reject δὲ from the text but wrongly. We have simply caught him napping here and have an insight into his method of work.

1570 = B. 45 ἦ [Eur. ὃς] *θεομαχεῖ τὰ κατά σε σπονδῶν τ' ἄπο* [Eur. *κατ' ἐμὲ καὶ σπονδῶν ἄπο.*] Here *θεομαχεῖ* was left in C., M., V. and the other resolved foot removed. It may be that this is to be explained by synizesis, as in A., B. it appears written *θυμαχεῖ*.

2219 = B. 668 *θέλω δ' ἀκοῦσαι, πότερά σοι παῤῥησίᾳ*. This is the reading of all the MSS. except A. (*πότερ' ὧς πάῤῥ.*) and V. (*πωτερον παῤῥ.*), which are evidently attempts to remove the objectionable foot.

1048 = B. 1244. This has been discussed on p. 374. It seems most probable that he found in his Euripides *μέγεθος*.

We have then shown how the author of the *Χρ. Π.*, when off his guard, followed his MS. of the Bacchae so closely, that he has introduced resolved feet in several instances, and also that the writer allowed himself the liberty to change a line to remove the objectionable tribrach. The conclusion must be drawn, that for Euripidean lines containing resolved feet the *Χρ. Π.* offers in all but a very few instances testimony of a very insignificant value. We have also demonstrated how slavishly in several instances he has followed his model to the sacrifice of grammatical and orthographical accuracy in his own composition. We feel, therefore, justified in affirming, that, inasmuch as in 48 cases he has preserved readings vastly inferior to those of our own MSS., cases in which a change is scarcely to be justified, the writer of the *Χρ. Π.* made use of a MS. of the Bacchae that contained a very corrupted text of that play. I cannot in view of facts here brought together agree with Dœring that the citations from the Bacchae in the *Χρ. Π.* have a high value for the text criticism of that play. Nor can I give assent to his statement, that the Euripidean MS. used by this writer should be placed for its excellence midway between the two classes of the Euripidean MSS. distinguished by Kirchhoff. The result of the present investigation has been to assign to a class much inferior to the existing MSS., which belong to Kirchhoff's second class, the MS. of the Bacchae that the author of the *Χρ. Π.* has used. Probably a careful investigation of the subject through the other plays of Euripides plundered by this ignorant writer would reveal the same state of affairs there also.

LIST OF CRUSTACEA CLADOCERA FROM MADISON, WISCONSIN.

By E. A. BIRGE,

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In 1878 the writer published Notes on Cladocera in the fourth volume of the Transactions of this Academy,* in which were noted twenty-five species of Cladocera found at Madison. Returning to the subject with better means of collecting and a much larger command of the literature of the group, I have been able to enlarge greatly the number of species and to identify them more accurately. As the task of reviewing the greatly scattered literature, especially of the *Lynceidæ*, seems likely to occupy some time, it seems advisable to print a list of the species already found, with notes on rare or new forms.

A glance at the subjoined list of sixty-four species and varieties regarded by many European writers as species, will show how close our fauna is to that of Europe. Out of the whole number, only nine are peculiar to this country and of these five are varieties of species found elsewhere, or are very close to foreign species. Three species are determined as new, *Latonopsis occidentalis* from the *Sididæ*, *Moina sp. nov.* from the *Daphnidæ*, *Alona lepida* from the *Lynceidæ*.

With the exception of five species and varieties (*Daphnia pulex*, *D. retrocurva*, *Alona tenuicaudis*, and the species of *Moina*), all of the species in the list have been found in Lake Wingra. This is a small lake about one and three-fourths miles long and half as wide, with broad margins of marsh all around it. In the marsh the water is from a few inches to two feet deep between the areas of wild rice and reeds, and the bottom is partly composed of vegetable débris and partly covered by a dense growth of *Chara*. The lake itself hardly exceeds fifteen feet in depth, and almost the entire bottom is overgrown with water plants of various kinds. Among these weeds and in the marshes Cladocera abound. The abundance of food and variety of locality offered probably account for the great number of species. In Lake Mendota, a much larger body of water, six miles by four, and having a depth of sixty to eighty feet, I have found only thirty-eight species of Clado-

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* Vol. IV, 1876-7 (printed 1878), pp. 77-110. Pl. I, II.

cera. Doubtless more careful and prolonged collecting would disclose new species in both bodies of water, but the larger lake is certainly poorer in number of forms, especially the littoral species. The pelagic forms are, of course, more abundant in the larger lake, and one variety has been found in Lake Mendota which Lake Wingra does not possess.

This single locality has yielded a number of species, comparing not unfavorably with the fauna described from England, Denmark or Russia. No European country shows more than 100 species; so that more than one-half of the probable fauna of Wisconsin has been found here. That so large a fraction of the entire fauna should belong to one locality will not appear strange when the similarity of the fauna to that of Europe is considered. If the species of Cladocera have so wide a range as appears from Sar's observations on Australian Cladocera, and from my work here, it is not probable that many species are strictly local. We should expect to find any given species over a large extent of country in suitable localities. This expectation has been realized in many cases. As conspicuous instances I may note the occurrence of *Drepanothrix dentata*, Eurén, in Wisconsin, the finding of *Dunhevedia setiger*, Birge, in Hungary by Daday, and the occurrence of *Ilyocryptus longiremis*, Sars, in Wisconsin and in Australia. No doubt some species are strictly local, confined to a small area, or the product of life-conditions existing there and not elsewhere. But the chance that this is true in any given case is small, and all well marked species should be looked for in every suitable locality. We should expect also that a locality especially favorable to the development of the Cladocera would contain a very large fraction of the fauna of the region.

The subjoined list also shows the value of long and careful collecting in one locality, and the impossibility of justly estimating the Cladocera of a lake from a single visit. The different forms behave much like the plants of a locality. Some species are present throughout the season. Some can be found only for a few days. Some come in the spring and disappear early, while others belong to the latter part of the open season. Of the nearly sixty species found in Lake Wingra I have never found more than thirty as the result of a single day's work. It is clear that a list of Cladocera compiled from a flying visit to a locality and containing from six to twenty species, has no claim to represent the fauna of that locality. Only careful collecting at intervals throughout an entire season can give even an approximate idea of the number of species present.

I may add that a single specimen was found in Lake Wingra, belonging to the genus *Anchistropus*, Sars, and apparently not to the species *emarginatus*, Sars. It was accidentally destroyed before it could be carefully studied.

LIST OF CLADOCERA FOUND AT MADISON, WISCONSIN.

1. *Holopedium gibberum*, Zad.
2. *Sida crystallina*, O. F. M.
3. *Daphnella brachyura*, Liév.
4. *Daphnella brandtiana*, Fisch.
5. *Latona setifera*, O. F. M.
6. *Latonopsis occidentalis*, spec. nov.
7. *Moina brachiata*, Jur.
8. *Moina*, spec. nov.
9. *Simocephalus vetulus*, O. F. M.
10. *Simocephalus serrulatus*, Koch.
11. *Ceriodaphnia megops*, Sars.
12. *Ceriodaphnia reticulata*, Jur.
13. *Ceriodaphnia pulchella*, Sars.
14. *Ceriodaphnia consors*, Birge.
15. *Scapholeberis aurita*, Fisch.
16. *Scapholeberis obtusa*, Schdl.
17. *Scapholeberis mucronata*, O. F. M.
18. *Daphnia pulex*, De Geer.
19. *Daphnia Schoedleri*, Sars.
20. *Daphnia minnehaha*, Herrick.
21. *Daphnia hyalina*, Leydig.
22. *Daphnia kahlbergensis*, Schoedler.
23. *Daphnia kahlbergensis*, var *cederstroemii*, Schdl.
24. *Daphnia kahlbergensis*, var. *retrocurva*, Forbes.
25. *Lathonura rectirostris*, O. F. M.
26. *Macrothrix rosea*, Jur.
27. *Macrothrix laticornis*, Jur.
28. *Drepanothrix dentata*, Eurén.
29. *Ophryoxus gracilis*, Sars.
30. *Ilyocryptus sordidus*, Liéven.
31. *Ilyocryptus longiremis*, Sars.
32. *Bosmina longirostris*, O. F. M.
33. *Bosmina longicornis*, Schoedler.
34. *Bosmina cornuta*, Jur.
35. *Bosmina bohemica*, Hellich. (?)
36. *Eurycercus lamellatus*, O. F. M.
37. *Leydigia quadrangularis*, Leydig.
38. *Alona quadrangularis*, O. F. M.
39. *Alona affinis*, Leydig.
40. *Alona lineata*, Fischer.
41. *Alona guttata*, Sars.
42. *Alona costata*, Sars.
43. *Alona tenuicaudis*, Sars.
44. *Alona lepida*, spec. nov.
45. *Graptoleberis testudinaria*, Fischer.
46. *Dunhevedia* (*Crepidocercus*) *setiger*, Birge.
47. *Pleuroxus trigonellus*, O. F. M.
48. *Pleuroxus denticulatus*, Birge.
49. *Pleuroxus gracilis*, Hudendorff, var. *unidens*, Birge.
50. *Pleuroxus exiguus*, Lillj.
51. *Pleuroxus excisus*, Fischer.
52. *Pleuroxus procurvatus*, Birge.
53. *Chydorus sphaericus*, O. F. M.
54. *Chydorus sphaericus*, var. *caelatus*, Schdl.
55. *Chydorus sphaericus*, var. *punctatus*, Hellich.
56. *Chydorus globosus*, Baird.
57. *Alonopsis latissima*, Kurz.
58. *Alonopsis media*, Birge.
59. *Acroperus leucocephalus*, Koch.
60. *Camptocercus macrurus*, O. F. M.
61. *Camptocercus rectirostris*, Schdl.
62. *Camptocercus biserratus*, Schdl.
63. *Polyphemus pediculus*, De Geer
64. *Leptodora hyalina*, Lillj.

NOTES ON THE PRECEDING LIST.

Species 1. HOLOPEDIUM GIBBERUM, Zad.

I have found this species only once in Madison. It is quite abundant in collections from northern Minnesota, and Forbes* notes its occurence at Grand Traverse Bay, Lake Michigan.

Species 2. SIDA CRYSTALLINA, O. F. Müller.

No specimens were found belonging to the form *S. elongata*, DeGeer.

Species 3 and 4. DAPHNELLA BRACHYURA, Liév. and D. BRANDTIANA Fisch.

Of those closely allied forms I have only to say that both are found with us, and show exactly the same differences as described and figured by Sars in his *Norges Ferskvandskrebsdyr. D. brachyura* is usually found in open water, and *D. brandtiana* in marshes. I cannot state this as a law, however, as both forms are found together sometimes, in either kind of locality.

Species 5. LATONA SETIFERA, O. F. Müller. Plate XIII. Fig. 6.

Our specimens of Latona have one peculiarity not mentioned by any European writer. There is a thick coat of short hairs on the head, body and antennæ. These hairs are .02 mm. or less in length, are close set and give the outline a velvety appearance when seen by transmitted light. P. E. Müller † says: "Hvad der er aldeles eiendommeligt for Latona og neppe jagttaget hos nogen anden Cladoceer, eret fint Lod af ganske korte Haar, der isaer findes over Matrix; det er vanskeligt at see og opdages kun ved staerkt Sidelys." This exact account shows that his specimens were not villous as ours are. The hairs are conspicuous in any light and are very easily seen. No other European writer mentions a similar structure. A more extended study of specimens from different localities will show whether this is a local peculiarity or is characteristic of a distinct variety. On old females which have not moulted recently the hairs are worn off.

The male antenna differs somewhat from the account given by Sars.‡ The *appendix ciliata* is much larger than Sars figures it, and is situated at the same level as the sense-hairs instead of distal to them. The size, number and arrangement of the setæ on the edge of the carapace differ from the details given by Sars, but not in any very important respect.

Latona seems to be rare in Europe, but the apparent rarity is, as Sars says, probably due to its mode of life and the method of collecting. In late summer and early fall, one can be certain of obtaining a good num-

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* Forbes, S. A. On some Entomostraca of Lake Michigan and adjacent Waters. Am. Naturalist, vol. xvi., p. 641. Aug., 1882.

† Müller, P. E. Danmarks Cladocera, pp. 97–98.

‡ Norges Ferskvandskrebsdyr, p. 55, Pl. III, figs. 17a, 17b.

ber at various localities near Madison. It lives in clear water among weeds, and a dredge which can be dragged *through* the weeds and not merely *above* them is needed in order to secure it. With the cone-dredge it is not difficult to obtain 20 to 100 specimens. The same may be said of such bottom forms as *Ophryoxus* and *Drepanothrix.*

Sars speaks feelingly of the difficulties which beset one who attempts to view this powerful and obstinate cladoceran from the side. If a life-box is used and a trace of ½ per cent. of solution of osmic acid in water is added to the water containing the animal, there will be little trouble in turning it on its side. After the poison begins to act, it is best to attempt turning the animal by rotating the cover of the life-box. If left to die undisturbed the antennæ are usually expanded while an irritation applied to it while alive causes it to fold the antennæ along its sides, when it can readily be turned into any position.

Species 6. LATONOPSIS OCCIDENTALIS, sp. nov. Plate XIII. Figs. 1–5.

In 1888 G. O. Sars* established the genus and species *Latonopsis australis* for a new form of the *Sididæ* raised by him from mud obtained from Australia. I have found here a second and closely allied species of this new and remarkable genus, and have succeeded in finding males which did not develope in Sars' aquaria.

Latonopsis, Sars, is closely alled to *Latona*, Sars, and may be characterized as follows:

LATONOPSIS, Sars.

Impression between head and thorax slight or wanting. Labrum devoid of plate-like expansion. Antennule with a long, plumose, straight or curved flagellum, articulated to the basal part. Antenna with simple rami, the superior ramus bi-articulate, the inferior tri-articulate, as in *Daphnella.* Heart concave dorsally, truncate anteriorly, the aorta arising on the ventral side. Shell-gland with three long branches. Male (of *L occidentalis*, Birge, at least) with simple copulatory organ, and hook on first leg. Antennule long, slightly curved, armed with fine teeth resembling in general the antennale of *Sida*, but having a median projection near the base. Color of both species yellowish-transparent.

SPECIES.

a. Fornices absent. Antennule shorter than anterior margin of head. *L. australis*, Sars.

b. Fornices present. Antennule longer than anterior margin of head. *L. occidentalis*, sp. nov.

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* Sars, G. O. Additional notes on Australian Cladocera raised from Dried Mud. Christiania 1888, pp. 6–15. Pl. I. Christiania Videnskabs Selskabs Forhandlinger 1888. No. 7.

DESCRIPTION OF FEMALE.

Length up to 1.8 mm. but usually smaller.

Measurements of average specimens.	♀ mm.	♂ mm.	♂ mm.
Length	1.30	.82	.61
Height	.80	.40	.27
Antennule	.42	.35	.28
Abdominal setæ	.50	.41	.31
Longest spine on carapace	1.05	—	.50

The head is in some cases marked off from the body by a slight depression, not seen in young specimens, and often absent in older individuals. The anterior outline of the head as seen from the side forms a straight or slightly convex line from the attachment of the antennules to the eye, where it passes by an abrupt curve into the dorsal margin. This margin is frequently continuous to the hinder end of the valves, and is nearly straight in young specimens but strongly convex in old females. Ventrally the anterior margin of the head terminates in a small projection to which the antennules are attached. The ventral margin is continued into the labrum, and is entirely devoid of the leaf-like expansion characteristic of *Latona*, Sars' *organum affixionis.* Above the insertion of the antennæ the valves are continued into small bilobed fornices, resembling those of *Latona* but much smaller, and not continued to the insertion of the antennules as are those of *Latona.* The head as seen from above is somewhat pyramidal in form.

The carapace does not differ greatly from that of the *Sididæ* in general. It leaves the oral structures uncovered in front; it is straight or convex dorsally according to the age of the animal; the ventral margin is evenly rounded and passes into the nearly straight posterior margin by a curve which forms no marked projection. The upper posteal angle is well marked. The edge of the carapace is fringed with long plumose setæ, each set on a small elevation. At the lower posteal angle are placed three setæ, much longer than the others. They are often longer than the carapace, and diverge from each other as they leave the shell, one passing nearly straight backward and the others more outward. These setæ are longer in our species than in *L. australis* as figured by Sars. The valves are not marked except by the braces (Stützbalken).

Along the inside of the hinder edge of the shell, from the insertion of the long setæ to the junction of the valves, runs a row of fine spines like those of *Latona.*

APPENDAGES.

The antennule consists of the basal part, the sense-hairs and the flagellum. The first is short, oblong, freely movable. The sense-hairs number about eight and are placed on the posterior side of the distal end of the base. The flagellum is attached to the base with a distinct suture. Sars calls it "distinctly articulated" in *L. australis*. Whether he means that there is a movable joint he does not make clear. In *L. occidentalis* there is simply a distinct suture. The flagellum is long, curved backward, tapers to a fine point, and is fringed with long straggling sense-hairs. These are far less numerous than in *Latona*. Most of them are on the anterior side of the antennale but at the tip they are attached to all sides. In this arrangement of the hairs the structure differs from the antennule of *L. australis* as figured by Sars. The sense-hairs are also longer than he shows them and the whole antennule is about twice as long, relatively, as that of *L. australis*.

The antenna closely resembles that of *L. australis*. The basal joint is exceedingly stout, so that the branches look too small for it. The dorsal sames is bi-, the ventral tri-articulate. The setæ are $\frac{4\,(5) - 7}{0 - 1 - 4}$ and the spines $\frac{1 - 1}{0 - 1 - 0.}$ The basal joint bears the usual dorsal sense organ at the base, and at the distal end are a spine anteriorly and a plumose sense-hair behind. The proximal joint of the dorsal ramus bears four well developed setæ, and sometimes a fifth, proximal, seta which is much smaller than the others. Its presence or absence seems to depend on no law, as it is either present or absent in specimens of all ages and both sexes and may be present on one side and absent on the other side of the same individual. All setæ are two jointed and densely plumose.

The proportionate length of individual setæ differs in my specimens from *L. australis* as figured by Sars. The terminal setæ of the dorsal ramus are little longer than the others in *L. occidentalis*. The seta of the second joint of the ventral ramus is as long as the largest on the distal joint and each is quite twice as long as any other seta on the branch.

The post-abdomen closely resembles that of *L. australis*. It is short, fleshy, obtusely conical, and armed with nine very small super-anal denticles. The abdominal setæ are two-jointed, plumose, each set on a fleshy projection. They are a little longer than those of *L. australis*. The terminal claws are strongly curved, and have two secondary teeth, of which the distal is the longer.

The mouth parts and legs seem to resemble closely those of the other *Sididæ*. No careful study of the legs, has, however, been made. They number six pairs, as in other *Sididæ*.

INTERNAL ORGANS.

In the structure of the internal organs *L. occidentalis* agrees closely with *L. australis*, and I can add little to Sars' account. The general arrangement of the organs of the head may been seen in the figures.

The heart as seen from the side, shows a tube convex below and concave above. It is truncated anteriorly, and the aorta issues from its ventral side. From above the heart closely resembles that of *Latona*, having the form of a broad sac, rounded behind, and widest through the venous ostia.

The shell-gland has a form in this genus, which is unique among the Cladocera. It consists of three branches, of which the shortest is dorsal and extends toward the heart, the next in length is ventral, while the longest extends posteriorly and may reach through two-thirds of the length of the valve. This last loop is found only in *Latonopsis.* The whole gland consists of a tube doubled on itself, whose course can easily be traced. Beginning near the mandible in a bladder-like expansion the tube passes into the valve and extends ventrally; it returns on itself to the middle point, then passes backward in a long loop, returns again to extend up toward the heart and come back to the middle. Then comes a second posterior loop, lying parallel to and within the first, and on its return the tube passes to its outlet near the mandible. Thus there are two passages in the dorsal and ventral loops and four in the posterior, not three as stated by Sars (op. cit. p. 9.). Sars' figure (Pl. I, Fig 1.) shows the organ quite correctly.

DESCRIPTION OF MALE.

The male resembles in general the young female.

The antennules are long and stout, being often nearly half as long as the animal. They taper toward the apex, are curved, but not geniculate. They are provided with a long row of very fine teeth extending from a point near the sense-hairs to the apex. They thus resemble in general the antennule of the male *Sida* and *Daphnella* and differ widely from the male *Latona.* Near the base of the antennule on the inner side is a stout projection, rounded at the apex and covered with very fine hairs. This projection is probably equivalent to the "appendix ciliata" of the male *Latona.** In *Latona*, Sars shows the appendix ciliata some way distal from the olfactory hairs, while in *Latonopsis*, it is some way proximad to these. My specimens of *Latona*, however, show the appendix close the to sense-hairs; so that the difference of position does not interfere with homology. The cilia on the appendix of *Latonopsis* are very fine and easily overlooked; they are far less conspicuous than in *Latona.*

The copulatory organs resemble those of *Latona.* They are a pair of long, curved, flexible appendages, perforated by the vasa deferentia. They arise at the base of the post-abdomen and are long enough to reach beyond the terminal claws.

The first leg shows a very distinct and strong hook. In this structure *Latonopsis* differs from the other *Sididæ* and especially from *Latona.*

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*Sars, G. O. Norges Ferskvandskrebsdyr. Cladocera Ctenopoda, p. 55. Pl. III, Fig. 17.

Sida, *Limnosida* and *Daphnella* have short, fleshy knobs rather than hooks, and *Latona* is devoid of any special structure. *Holopedium* has a hook similar to that of *Latonopsis* but much longer, as is natural in that genus.

The new hatched male has the copulatory organ in the form of a pair of small buds, which do not reach the adult form until after four or five moultings. The antennule of the young male differs widely from the adult form. It is short, lacks the appendix ciliata, and shows a distinct suture between base and flagellum. The latter is covered with long straggling hairs. The whole structure closely resembles the female antennule. It is clear that the extension of the male antennule beyond the sense-hairs in the homologue of the flagellum of the female.

RELATIONS OF THE GENUS.

Sars was entirely justified in separating *Latonopsis* from *Latona*. While the structure of the two genera is quite similar in the female, the male differs widely from that of *Latona*. The antenna is more like that of *Daphnella* than that of any other genus, especially in the rami, while the great development of the base is like that of *Latona*. The antennule is peculiar and shows an intermediate stage between that of *Latona* and *Daphnella*, though nearer the former. In the male, however, the antennule is more like that of *Sida* than that of *Latona*. In the form of the body, the outline of the head, in the fornices, the position of the eye, eye-muscles and optic ganglion; in the heart; in the shape of the carapace, and the development of the setæ of the carapace, it approaches *Latona*. It lacks entirely the peculiar development of the antenna seen in *Latona* and the plate on the lower side of the head; while *Latona* lacks the development of the shell-gland, which *Latonopsis* shows. In most of the points of resemblance and difference between the two genera, *Latonopsis* is nearer the ordinary form of the *Sididæ*, and it may be considered as connecting *Latona* with the other *Sididæ*, but with many cross-relations to other genera.

RELATIONS OF THE TWO SPECIES.

L. occidentalis is very close to *L. australis*. Indeed, I am not sure but that they are really the same species. There are many points of minor difference, but the most tangible is the antennule, which is about twice as long in the American form. It must not be forgotten, however, that Sars' specimens were hatched from mud, and it may be possible that specimens collected in their native waters will agree more closely with the American species. If the difference is constant, *L. australis* is nearer the ordinary type of the *Sididæ* in the structure of the antennule.

BIOLOGICAL REMARKS.

Latonopsis occidentalis was found in Lake Wingra, a small lake about one and three-fourths miles long with a broad margin of marsh. It lives chiefly in the marshy region although I have found it in deeper water — one to three meters. It is most abundant in openings among the reeds of the marsh, where there is a foot or so of water filled with algæ and vegetable débris. In one such spot it was especially abundant during the summer of 1891. A single haul of the dredge would give from six to thirty individuals. I have dredged it with *Latona* in the open water, while I have never found *Latona* in the marsh. Sars' specimens came from a clayey mud. I have never found this species in muddy water.

In the aquarium it behaves quite like *Latona*. It often remains suspended and motionless in the water, and can often be turned over with the dropping tube without disturbing it. When, however, it decides to move it starts very suddenly. Its movements are less vigorous than those of *Latona*, as would be inferred from the different structure of the antennæ.

I have never seen more than eight young in the brood cavity. There are two sexual eggs, for whose reception a special cavity is enclosed, although there is no true ephippium.

The males appear in the latter part of July and the first part of August, and in September no specimens of either sex could be found, while *Latona* was more plentiful at this time than earlier in the season. Constant observation at any small lake will convince the student that the appearance of the males does not depend on temperature or any other simple cause. Each species has its own time for sexual reproduction, which is related to external influences in the same complex way as is the flowering of plants.

Species 8. MOINA, spec. nov.

A species of *Moina*, apparently new, has been found, but it is not as yet thoroughly worked up and will probably form the subject of a special paper. It seems related to *M. brachiata*, Jur. and was at first identified with this species. Further study, however, showed that there was only one egg in the ephippium and that the structure in other particulars differ from *M. brachiata*. The male especially shows peculiarities not found in other species.

Species 21. DAPHNIA HYALINA, Leydig. Plate XIII. Fig. 9.

Into this species have been united *D. galeata*, Sars, *D. pellucida*, P. E. Müller and *D. gracilis*, Hellich. Two well marked varieties are found at Madison. One with pointed crest is found in Lake Wingra, and the other whose crest is rounded is found in the larger lakes. Although the lakes are only a mile apart, I have not found the pointed variety in Mendota or the rounded in Wingra. The outlines of the head are very variable, the variations quite closely resembling those represented in *D. berolinensis*, *apicata*, and *cucullata*, although of course this species has the macula nigra.

The males appear in the latter part of September. The flagellum of the antennule is convex, stout and short, usually little longer than the sense-hairs. The anterior sense-bristle in our specimens lies little nearer the end of the basal portion of the antennule than the head. In this our specimens differ from Eylmann's * description, who says of it, that it is "von der Endborste nicht weit entfernt."

This species is the most abundant in the open waters of the Madison lakes. I have also obtained it from Minnesota and Michigan, showing some variation from our form in each case.

Species 24. D. KAHLBERGENSIS var. RETROCURVA, Forbes. Plate XIII. Figs. 7, 8.

This form was first described by Forbes * as a distinct species. It is the most extreme Daphnid form yet observed. I cannot agree in the statement of Forbes that the large helmeted forms predominate in the smaller lakes (l. c. p. 643.) At Madison the forms of *D. hyalina* and of *D. retrocurva* in Lake Mendota are much more helmeted than those in Lake Wingra. The former lake is about six miles by four, the latter 1¾ by ¾ mile. *D. hyalina* in the smaller lake is more like *D. apicata*, while in Mendota the crest is more developed than is shown by any European descriptions. *D. kahlbergensis* from Wingra shows the forms typical of that species and of *cederstroemii* while the full development of the crest only comes in the larger lake. The males of this species appear late in the fall, in the latter part of October and in November. The head is of the *kahlbergensis* type, sometimes curved up but never showing the extreme development of the female. The antennule has a flagellum a good deal longer than the sense-hairs, curved at the tip and distinctly articulated to the basal part.

Our specimens do not show the extreme development of the head before birth noted by Forbes (l. c., p. 642). The head in the young is not as much crested as in the adult *D. hyalina*. This species is always found in company with *D. hyalina* and is far less numerous. On calm summer nights the water of Lake Mendota swarms with these two species, together with a *Cyclops*, a *Diaptomus*, and *Leptodora hyalina*. They are not abundant close to shore and seem to spend the day in swarms at the

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* Eylmann, E. Beitrag zur Systematik der Europäischen Daphniden, Freiburg i. B. 1886, p. 33.

* Forbes, S. A. Entomostraca of Lake Michigan and adjacent waters. American Naturalist. Vol. xvi., p. 642, August, 1882.

bottom where the vegetation consists mainly of diatoms, outside of the growth of weeds. The number of the Cladocera is simply incalculable. I do not think that any shallow water is more filled with crustacean life than are the open waters of our lakes. Dredging does not give a fair idea of the number of open water individuals. Only surface collecting at night will disclose them.

Species 26. MACROTHRIX ROSEA, Jurine. Plate XIII. Figs. 13, 14.

I have succeeded in finding several specimens of the male of this species and have materially increased the accuracy of my knowledge of its structure. I found a single male in 1877 which was described in the Transactions of the Wisconsin Academy, Vol. IV. p. 90. Since that time the male has been seen by Daday,* who gives a figure which, however, is so small and shows so little detail that it does not add much to our knowledge.

The male antennules are long and curved, provided with a long anterior sense-hair at the base. They are curved toward the median plane of the body at the tip and bear the olfactory hairs on a small elevation on the anterior side. On the posterior side of the apex is a cluster of 5–6 long diverging sense-hairs. Daday shows these in his figure, but does not mention them in the text. In the possession of this extra sense organ, the male *M. rosea* differs from all other male Cladocera known, including the closely allied *Macrothrix laticornis*. These sense-hairs were not seen by me in my earlier specimen.

The post abdomen is prolonged into a flexible projection, on whose summit the vas deferens opens, just before the very small terminal claws. The whole structure thus resembles that of the male *Bosmina*.

Species 27. MACROTHRIX LATICORNIS, Jurine.

This form, which is usually given as the commonest of European species seems very rare here. I have met with not more than a dozen specimens in a season's collecting, while *M. rosea* is very abundant in marshes. It is at times the predominant cladoceran, while *M. laticornis* has never appeared except in single specimens.

Species 28. DREPANOTHRIX DENTATA, Eurén. Plate XIII. Figs. 15–17.

1861. *Acantholeberis dentata*, Eurén, Om märkliga Crustaceer af ordningen Cladocera, funna i Dalarne. Ófvers, af K. Vet.-akad. Förh. 1861, p. 118. Description of female. Tafl. III, fig. 2. Female.

1862. *Drepanothrix sentigera*, Sars, G. O. Om de i Omegnen af Christiania jagttagne Crustacea cladocera. Forh. Vid.-Selskab. i Christiania, 1862, p. 156. Description of male and female.

1862. *Drepanothrix hamata*, Sars., Do. p. 300. Mention only.

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* Daday, E. Crustacea Cladocera Faunae Hungaricæ, p. 106, Pl. II, fig. 43.

1867. *Drepanothrix hamata*, Norman and Brady. Monograph of the British Entomostraca belonging to the families Bosminidae, Macrothricidae and Lynceidae. Nat. Hist. Trans. Northumberland and Durham, 1867, p. 12, description of female. pl. XXII, figs. 5 female, 6, antennule, 7 post-abdomen.

1867. *Drepanothrix dentata*, P. E. Mueller. Danmarks Cladocera, p. 138. Description of female. Pl. II, fig. 13, antennule.

1884. *Drepanothrix dentata*, Herrick, C. L. Geol. and Nat. Hist. Survey, Minnesota. 12th Report, 1884, p. 73. Description from P. E. Mueller. Plate C, fig. 14, antennule, from P. E. Mueller. In the description of the genus the word "not" should be erased in the first sentence, "The head *not* separated from the valves by a depression."

1888. *Drepanothrix dentata*, Richard, J. Recherches sur la Faune des Eaux du Plateau Central. Clermont, 1888. Mention only.

The references given above show that this rare species occurs in Denmark, Scandinavia, Great Britain and France. I have found it here in both sexes and in considerable numbers. Sars' description is accurate, as is that of Norman and Brady. The vas deferens opens in front of the terminal claws without any prolongation of the base into a penis.

D. dentata is found in Lake Wingra at a depth of from 5–10 feet. It is most abundant in a particular zone of depth in that lake where the weeds of the marshy margin cease and those of the deeper water have not come in abundantly. Here is a stretch of bottom a few yards in width composed chiefly of broken up snail shells and vegetable debris and with a few Charae as the chief living plants. In this zone I have found this cladoceran quite common. It is not confined to it, however, but is met with both inside and outside of this limit. In the marsh proper, however, I have never found it. It is a bottom-haunting form and is therefore difficult to obtain in large numbers.

Under some conditions it is markedly repelled by light. If a portion of the bottom with this and other Cladocera is placed with water in a watch glass and the whole exposed to strong light as from a lamp, *Drepanothrix* will at once hurry to the side remote from the source of light. While *Chydorus*, *Pleuroxus*, *Daphnia* and most other forms present will congregate on the side toward the light, *Drepanothrix* hastens away from it in an awkward scramble. The sabre-like setae from which its name is derived are its chief organ of locomotion. These it uses much as a boy uses a pair of sticks to propel his sled over the ice. It can swim fairly well in the open water, but is hampered by the weight and stiffness of these setæ.

Species 29. OPHRYOXUS GRACILIS, Sars. Plate XIII. Figs. 10–12.

1862. *Ophryoxus gracilis* Sars, G. O. Oversigt af de i Omegnen af Christiania jagttagne Crustacea cladocera, p. 158. Description of male and female.

(?) 1875. *Ophryoxus paradoxurus*, Hudendorff, A. Beitrag zur Kenntniss der Süsswasser-Cladoceren Russlands, p. 43. Description of female. Tab. II., fig. 1, a. b. This species, founded on a single specimen, very possibly belongs here.

1882. *Lyncodaphnia macrothroides*, Herrick, C. L. American Naturalist, Vol. XVI, p. 1006. Description of female. Plate XVI. figs. 1, female, 2, antennae, 3, post-abdomen, 4, antennule.

1884. *Lyncodaphnia macrothroides*, Herrick, C. L. Geol. and Nat. Hist. Survey of Minnesota, 12th Annual Report, 1884, p. 74. Description of female. Pl. B, fig. 12, yg.; 13, labrum; 14, antennule; 15, last foot. Pl. B, 1, figs. 1, female; 2, post-abdomen; 3, antennule.

Ophryoxus is quite abundant in Lake Wingra, occurring through the the entire summer in openings in the marsh. It is nowhere rare, and never very plentiful. It seems to have the habit of a *Daphnia*, swimming feebly about in the open waters, rather than clinging to weeds. I give figures of the head, first leg, and the post-abdomen of the male, which have never been illustrated.

The statement that the young have a long spine, (Sars), or that the young differ in form from the adult (Herrick), need qualification. The form never differs greatly from that of the adult, and there is never any difficulty in recognizing it as the young of *Ophryoxus*. Indeed, the presence of the spine is the only important difference between the young and old. This spine is not long according to the standard of the genus *Daphnia* as it rarely measures more than ¼ of the length of the animal. It is possessed by the male as well as by the young female. In the adult female it is reduced to a sharp prominence, like that seen in many species of *Ceriodaphnia*.

Species 31. ILYOCRYPTUS LONGIREMIS, Sars. Plate XIII, fig. 18.

1888. *I. longiremis*, Sars. Additional notes on Australian Cladocera, Christ. Vid.-Selskabs Forhand. 1888, No. 7, p. 33–41. Description of male and female. Pl. iv. figs. 1, female; 2, female from below; 3, spines from edge of shell; 4, female post-abdomen; 5, male.

I am unable to distinguish our specimens from those raised by Sars out of mud from Australia. The antennary setæ, from whose length the name is derived, are even longer in our species than in Sars' figures, nearly equalling the total length of the animal. There are 5–7 superanal teeth, largest in the middle, an outer row of about eight long postanal spines and an inner row of 11–12 post-anal denticles besides several very small teeth near the terminal claw. There are 3–4 denticles on each side of the anus. This armature of the post-abdomen distinguishes the species at once from *Ilyocryptus sordidus* and *I. acutifrons*, while the antennary setæ distinguish it from *I. agilis*. The fact that moulting is imperfect also serves to distinguish it from the latter species.

This is the common form of *Ilyocryptus* here, and is very abundant in shallow water and marshy localities throughout the summer and until after the formation of ice in the winter. The failure of food consequent on long continued cold seems the only thing which checks their multiplication. Whether *I. spinifer*, Herrick (op. cit., p. 77), is identical with this species can not be decided as none of the specific characters are mentioned or figured.

Species 37. LEYDIGIA QUADRANGULARIS, Leyd.

The shell-markings in my specimens are far more distinct than those described by European authors. Otherwise the species agrees entirely with the descriptions.

Species 40. ALONA LINEATA, Fischer.

If, following Matile's * advice, the specific name *lineata* is abandoned, my form would be *A. pulchra*, Hellich.

Species 44. ALONA LEPIDA, sp. nov. Plate XIII. Fig. 19.

Length, .8 mm.	Length of male, .6 mm.
Height, .45-50 mm.	Height of male, .3 mm.
Length post-abdomen, .40 mm.	

General shape conforms to the normal Alona type. Head depressed, rostrum sub-acute, nearly reaching the level of the ventral margin of the shell. Valves quadrangular, dorsal margin arched, superior posteal angle obtuse, well-marked. Posterior margin oblique, bearing a row of minute spinules. Inferior posteal angle rounded, very slightly emarginate. Ventral margin beset with a row of plumose setæ, of ordinary length, which ends abruptly at the posteal angle. Valves marked by close-set, conspicuous, longitudinal striæ, alternately stronger and weaker, occasionally anastomosing, running parallel to the dorsal and ventral margins and converging into a reticulated area at the anterior inferior portion of the valves. Between the striæ lie the braces.

Antennule extends nearly to end of rostrum: is spindle-shaped, largest near base, provided with an anterior sense-bristle and 6–8 subequal sense-hairs. Antennary setæ $\frac{300}{311}$. The terminal setæ are of unequal length. All are plumose and without spines. The eighth setæ is of moderate size, bi-articulate and plumose. Spines of antennae, $\frac{101}{100}$. On the middle joint of the inner branch is a circlet of small spines. Ventral margin of labrum often notched just anterior to the posterior angle,

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* Matile, P. Die Cladoceren der Umgegend von Moskau, 1890, p. 46.

which is sharp. Eye moderate in size, showing four or fewer lenses. Macula nigra about as large as eye, angular, and somewhat nearer to eye than to apex of rostrum.

Post-abdomen enlarged posteriorly, lower angle rounded, bearing 15–17 serrate post-anal denticles and about the same number of squamae. Terminal claws smooth. Basal spine rather large. Abdominal setæ of ordinary length.

MALE.

Antennule cylindrical, with anterior sense-bristle and flagellum. Post-abdomen devoid of denticles and with a row of squamae. Vas deferens opens in front of terminal claw. Basal spine large.

Color yellowish to bright yellow, fairly transparent. Lake Mendota, in deeper water, 15–20 feet.

This species is evidently related to *A. elegans*, Kurz* from which it differs in its greater size, in the reticulation of part of the shell, and in the size, shape and armature of the post-abdomen. The post-abdomen of *A. lepida* resembles in general that of *A. quadrangularis*, O. F. M. The species lives at the bottom in rather deep water — 15–20 or more feet — and is much more abundant in Lake Mendota than elsewhere in the vicinity of Madison.

Species 45. GRAPTOLEBERIS TESTUDINARIA, Fischer.

My species *G. inermis*,† is a variety of this species. The spine on the terminal claw is sometimes, though rarely, present, and the other characters adduced for *G. inermis* fall within the range of variation of European forms.

Species 46. DUNHEVEDIA (CREPIDOCERCUS) SETIGER, Birge. Plate XIII. Fig. 20.

In 1888, G. O. Sars‡ raised from dried mud and redescribed *Dunhevedia crassa* of King. From his description and figures it is plain that my genus *Crepidocercus* is identical with King's *Dunhevedia*, which was established in 1853. The genus was named by King from Dunheved, the place where the animal was found. My species differs from *D. crassa*, King, in the reticulation of the shell and, apparently, from *D. podagra*, King, in general form. I have not been able to see King's original paper. *D. setiger* has been found in Hungary by Daday.§

In the latter part of August I found the males of this species. *D. setiger* has always been one of the rarest species of Cladocera here. It was rarely collected at all, and if present in a dredging was found in only

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*Kurz, W. Dodekas neuer Cladoceren. Sitzb. der K. Akad. der Wissensch. Wien; 1874. Separate reprint, p. 43. Description of female, Tab. II, fig. 1, female.

† Transactions Wis. Acad. Sci., vol. iv, p. 102, pl. I, fig. 17.

‡ Additional notes on Aust. Cladocera, 1888, p. 41, Pl. 5, figs. 1-4.

§ Daday, E. Crustacea Cladocera Faunæ Hungaricae, p. 93, Pl. I, fig. 47-48.

one or two specimens. At the time named I found in Lake Wingra, in water filled with *Millefolium*, immense numbers of the species in both sexes. Thousands were collected in a single haul of the cone-dredge. After about a week they disappeared and repeated efforts to find them in the same locality failed. Doubtless the winter eggs had been laid and both sexes were dead. It will be interesting to observe at what date the species will appear in 1892.

The male measures about .36 mm in length and .24 mm in height. It has the same general form as the female. The first foot has a stout hook. The post-abdomen resembles that of the female, and is provided with numerous scattered hairs. The vas deferens opens above the terminal claws. The terminal claws are smooth in both sexes, differing from *D. crassa* in which they are denticulate.

Species 47. PLEUROXUS TRIGONELLUS, O. F. Mueller.

This species is by no means abundant here, and is usually found in deep water, down to 12–15 feet.

Species 48. PLEUROXUS DENTICULATUS, Birge. Plate XIII. Fig. 21.

This is the ordinary *Pleuroxus* here. It corresponds to *P. aduncus*, Jur. in Europe. I give a figure of the male post-abdomen.

Herrick remarks on the similarity of this species to *P. procurvatus*, and suggests that the two names may really belong to varieties of the same species. I have looked carefully for connecting forms but have been unable to find then.

Species 49. PLEUROXUS GRACILIS, Hudendorff, var. UNIDENS, Birge.

I was not acquainted with Hudendorff's paper when I wrote my description of this species in 1877. Matile* notes the resemblance of the two forms and correctly points out that the chief difference lies in the overhanging projection of the upper posteal angle in *P. unidens*. As I find this difference constant and as there are other less important differences, I retain my name as characterizing a variety. Both Hudendorff and Matile note the species as rare. I did the same in my former paper, having then found only about 15 specimens. By the use of the cone-dredge I have found it quite abundant in Lake Wingra in late summer and autumn. There is no difficulty in getting 25 to 100 specimens from one haul of the dredge.

Species 60–62. CAMPTOCERCUS.

Three species of *Camptocercus* are found in Wisconsin. *C. macrurus*, O. F. M. has been formed in only a few specimens.

I am doubtful whether Schoedler's two species *C. biserratus* and *C. rectirostris* are really distinct. I find forms agreeing with both descriptions

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* Die Cladoceren der Umg. von Moskau, 1890, p. 37.

in general, and include both names. In no case have I found the head directed so horizontally forward as in Schoedler's figures of *C. rectirostris.** Nor are the posteal teeth so large. Our form more nearly resembles that figured by Matile.† In the other form, the head is more depressed, the macula nigra larger than the eye, and the ventral margin of the valves is concave. I have found no specimens connecting the two forms and have therefore identified them as above.

In both species I have found individuals in which the beak was truncate, resembling that part in *C. Lilljeborgii*, Schdl., as figured by Hellich,‡ or *C. latirostris*, Kurz.§ The shell markings differ from those figured by any author. If a cast shell is examined without cover glass and not covered by water, a reticulated area is seen in the anterior part of the valves just below the middle. From this radiate most of the striæ. These are in front parallel to the anterior edge of the shell and the direction gradually changes until they are parallel to the ventral edge. Sixteen or more striæ run out on the ventral edge of the shell. The longitudinal striæ anastomose occasionally and those on the dorsal part of the valves do not bend downward into the reticulated area. I have never found specimens reticulated all over with quadrangular meshes as Hellich (l. c., pp. 76–77) figures them.

Species 63. POLYPHEMUS PEDICULUS, De Geer.

This species I have found very rarely. Only two or three specimens have been discovered at long intervals. Zacharias‖ notes that this animal is distinctly northern in its range. My observations confirm his conclusion. I find it quite abundant in a small collection from northern Minnesota. Herrick also describes it as plentiful in Minnesota. As I have often searched vainly for it here, I believe that this locality must be close to the southern limit of its range. The same is probably true of *Holopedium gibberum*, Zad.

Species 64. LEPTODORA HYALINA, Lillj.

I quote this species by its old name, without passing on the correctness of the change to *L. Kindtii*, Focke. Focke's paper is inaccessible to me. *Leptodora* is very abundant in all our lakes. It grows to a large size and specimens 18–21 mm. in length are not rare.

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* Schoedler. J. E. Neue Beiträge zur Naturgeschichte der Cladoceren, 1853. Pl. III, fig 50.

† Matile, P. Die Cladoceren der Umgegend von Moskau. 1890. Pl. IV, fig.26.

‡ Hellich, B. Die Cladoceren Boehmens, 1877, p. 77, fig. 37.

§ Kurz, W. Dodekas neuer Cladoceren, 1874, Pl. II, fig. 9.

‖ Zacharias, O. Die Fauna des grossen und kleinen Teiches in Riesengebirge, Zeit. Wiss. Zool. Vol. XLI., p. 492.

THE CONE-DREDGE.

The dredge which I have used for collecting seems worthy of special description. It consists of four parts: the body, the cone, the net, and the screw-top. The body is a cylinder of stout tin, strengthened by a wire at each end, four inches long, and four inches in diameter. On top of this is placed a cone of brass netting, five inches high. This is attached below to a circle of tin so that it fits into the top of the body like the cover of a tin pail. The bail of the body is of stout brass wire; the ends passed through the side of the body and enlarged, and the loop of wire shaped so as to fit within the cone and project through a hole in its top with an eye into which the dredge-line can be fastened. To the end of the line is attached a snap-hook larger than the hole in the top of the cone, so that the cone can not come off the body when in use. There are two cones provided for my dredge, one of one-tenth inch mesh, and the other of one-twentieth inch.

The $\frac{1}{20}$ inch mesh is coarse enough unless it is desired to secure very large forms. For ordinary shallow water collecting it is the best size. The cone can easily be removed for work at night in the open water.

The net is of fine cheese cloth, eighteen to twenty-two inches long, conical, large enough at the base to slip over the dredge body, to which it is tied. It is faced with stout muslin for a distance of two or three inches at each end. At the smaller end it is small enough to fit the screw-top, a tin cylinder one inch in diameter and one and one-quarter inches in length, with a wire in one end and on the other a zinc screw-top, such as are used on kerosene cans.

The seam along one side of the net is so made as to leave a sort of a loop in the cloth, through which a string can be run. One end of this string is tied about the dredge body; to the other end can be attached a weight, when desired, without having the pull of the weight come on the net.

This dredge is very useful for collecting small animals in shallow or weedy water. It can easily be thrown from the shore to a distance of 50 feet or more, thus permitting much more extensive collecting from shore than does the ordinary hand net. It can be drawn through weeds and over muddy bottoms, straining large amounts of water without becoming filled with mud or clogged with weed. If it is desired to collect from water close to the bottom without obtaining mud, a weight fastened to the end of the cord spoken of, so as to drag behind the dredge will cause the dredge to lift at each pull and so exclude most of the mud, except in very deep water. If a band of cloth is fastened about the base of the cone, leaving only the upper part free it will admit the water just above the bottom without scraping up mud. An old rake or other irregular piece of iron fastened to the dredge-line in front of the dredge will stir up the bottom and thus samples of bottom animals can be gathered from a long distance, before the dredge fills. The cone not only excludes weeds but also keeps out insects, larvæ, large Gammari, etc., which so abound in localities favorable for Cladocera, and whose size and activity made it difficult to distinguish the smaller crustacea in the collector's jar. The fact that this dredge can be pulled through weeds and strain a large quantity of water without obtaining a large amount of vegetable debris makes it very valuable in obtaining the rarer Cladocera.

The dredge is emptied by unscrewing the screw-cap and washing out the contents of the bag into a tumbler or small jar of water. In collecting near home this is brought to the laboratory for study. When it is desired to preserve collections for future study, the water is allowed to stand and settle for a short time and then the clear water containing the animals and free from mud is poured through a funnel into a small bag of cheese-cloth which is tied and put into alcohol or other preserving fluid.

With this dredge it is not at all difficult to collect 20–30 species of Cladocera from one locality and in a few hauls. In a collection thus gathered from the shore on a flying trip to some small lakelets at Manistee, Mich., I found twenty-six species of littoral Cladocera. Zacharias* in a summer's campaign in North German lakes found only twenty-three species from the shore waters.

PLATE XIII.

Fig. 1. *Latonopsis occidentalis*, Birge. Head of male, enlarged 60 diameters.
Fig. 2. “ “ Head of young female, enlarged 50 diameters.
Fig. 3. “ “ Post-abdomen of male, enlarged 75 diameters. The spines of the carapace are omitted.
Fig. 4. “ “ Antennule of new-hatched male, enlarged 200 diameters.
Fig. 5. “ “ First leg of male, enlarged 175 diameters.
Fig. 6. *Latona setifera*, O. F. M. Male antennule to show position of *appendix ciliata* (a). Enlarged 200 diameters.
Fig. 7. *Daphnia retrocurva*, Forbes. Male antennule, enlarged 200 diameters.
Fig. 8. “ “ Female, enlarged 30 diameters.
Fig. 9. “ *hyalina*, Leyd. Male antennule, enlarged 200 diameters.
Fig. 10. *Ophryoxus gracilis*, Sars. Head of male, enlarged 65 diameters.
Fig. 11. “ “ Post-abdomen of male, enlarged 160 diameters.
Fig. 12. “ “ Part of first leg of male, enlarged 200 diameters.
Fig. 13. *Macrothrix rosea*, Jur. Antennule of male, enlarged 240 diameters.
Fig. 14. “ “ Post-abdomen of male, enlarged 240 diameters.
Fig. 15. *Drepanothrix dentata*, Eur. Post-abdomen of male, enlarged 175 diameters.
Fig. 16. “ “ Female, enlarged 65 diameters.
Fig. 17. “ “ First leg of male, enlarged 300 diameters.
Fig. 18. *Ilyocryptus longiremis*, Sars. Male, enlarged 100 diameters. The spines of the carapace are omitted where they would cross the post-abdomen.
Fig. 19. *Alona lepida*, Birge. Cast shell to show markings, enlarged 60 diameters.
Fig. 20. *Dunhevedia setiger*, Birge. Male, enlarged 115 diameters.
Fig. 21. *Pleuroxus denticulatus*, Birge. Post-abdomen of male, enlarged 165 diameters.

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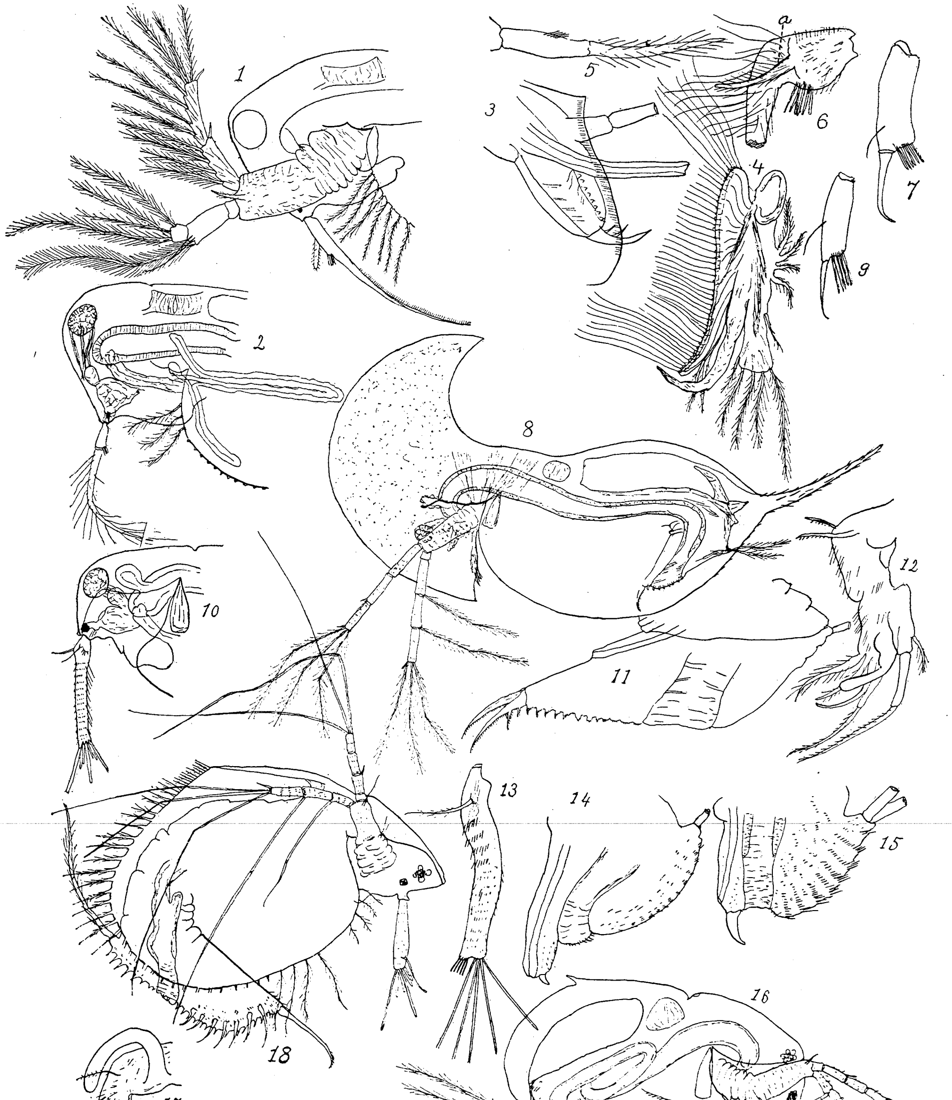
* Zacharias, O. Zur Kenntniss der pelagischen und littoralen Fauna Norddeutschen Seen, Zeit. Wiss. Zool. Vol XLV, 1887., p. 265.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NOTE ON CERUSSITE FROM ILLINOIS AND WISCONSIN.

By WM. H. HOBBS.

A few years since the University of Wisconsin obtained by purchase the mineral collections of W. T. Henry, of Mineral Point, Wis. They consist largely of the minerals associated in the zinc and lead deposits of southwestern Wisconsin and northwestern Illinois, and comprise the best series existing from that region. Among the carbonates cerussite is found, the best localities being Galena, Ill., and several points in Iowa County, Wis.

In a number of specimens in the University of Wisconsin collections the mineral is quite well crystallized and is always found on the surface of galenite, where its presence is best explained by the action of carbonated waters on the galenite. Cubes of galenite attaining in some cases dimensions of several inches are half covered by yellowish white cerussite crystals, which vary in size from a millimetre to more than a centimetre in diameter. They are stoutly columnar and translucent, with a color varying from yellowish white to light steel-gray. The faces are generally somewhat rounded, especially the terminal ones. The brachy-axis is the one of principal development, the columnar habit being given by the planes s, $\frac{1}{2}P\breve{\infty}$ (012), and u, $2P\breve{\infty}$ (021), which have about equal development. The fundamental prism M terminates the crystals. The pyramid t, P (111) appears as a rounding of the combination edge M : s. Twins parallel to M were frequently observed. Measurements of the interfacial angles with the goniometer of the Fness *Universal-apparat* gave the following results:

	Measured	Calculated.
u : u ($2P\breve{\infty}$: $2P\breve{\infty}$)........................	111° 2′	110° 40′
s : s ($\frac{1}{2}P\breve{\infty}$: $\frac{1}{2}P\breve{\infty}$)........................	139° 54′	140° 15′
M : M (∞P : ∞P)........................	117° 25′	117° 14′
t : t (P : P)........................	130°	129° 30′

The face t gave no image, the value being the average of a number of measurements by the shimmer seen when the lens was in place before the telescope.

Figure 1 shows the average development of an untwimmed individual.

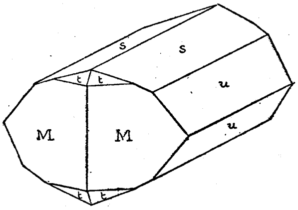

Fig. 1.

Mr. R. B. Green, late of the University of Wisconsin and now chemist for the Lake Superior Iron Company at Ishpeming, Michigan, has made an analysis of some of the more translucent crystals from Galena, Illinois, with the following results:

		Calculated for Pb Co_3.
Pb O	83.42	83.52
CO_2	16.45	16.48
	99.87	100.00

The material analyzed was specially examined for zinc with negative results.

University of Wisconsin.

PROCEEDINGS.

PROCEEDINGS.

NINETEENTH REGULAR MEETING.

THURSDAY, December 27, 1888, 4 P. M.
COMMITTEE ROOM OF SENATE CHAMBER.

Report of treasurer and secretary read.

That of secretary approved.

The committee on nominations (Prof. Van Hise, chairman), reported the following candidates, all of whom were elected:

C. C. Pudor, Madison.
Prof. C. D. Marsh, Ripon.
Frank Leverett, U. S. G. S., Madison.
Prof. G. C. Comstock, Madison.
G. B. Ransom, U. S. Navy, Madison.
F. W. A. Woll, Madison.
Prof. Stephen M. Babcock, Madison.
Prof J. S. Brown, Madison.
Dr. H. B. Favill, Madison.
Dr. Jos. Jastow, Madison.
Prof. J. E. Olson, Madison.
Prof. W. A. Henry, Madison.
F. G. Short, chemist, Experiment Station, Madison.
Hon. G. H. Noyes, Milwaukee.
H. J. Desmond, Milwaukee.
Dr. H. A. Puls, Milwaukee.
Dr. J. M. Dodson, Milwaukee.
J. H. Dawley, Antigo.
Prof. J. Bigham, Ripon.
J. B. Thayer, Madison.

W. H. Chandler, Madison.
Prof. Storm Bull, Madison.
Rev. A. N. Somers, Ft. Atkinson.
Rev. H. D. Maxson, Menomonie.
Prof. C. S. Slichter, Madison.
Prof C. H. Chandler, Ripon.

THURSDAY, 7:30 P. M.
ASSEMBLY CHAMBER,

Joint meeting of Academy and Teachers' Association.

Paper—Importance of Libraries in Rural Schools—Hon. J. B. Thayer.

Paper—Socialism and Anarchy—Rev. H. D. Maxson.

Adjourned.

FRIDAY, Dec. 28, 9 A. M.
ROOMS OF THE ACADEMY.

Prof. Allen in the chair.

Auditing committee appointed consisting of Prof. L. M. Hoskins and Prof. Chandler.

Committee on nominations appointed consisting of Prof. Van Hise, Prof. I. M. Buell and Prof. A. J. Rogers.

The following papers were read:

"Observations on the Till Aggregations in South Eastern Wisconsin."—Prof. Ira M. Buell.

"Appendages of the First Abdominal Segment of the Embryo of the Cockroach."—W. M. Wheeler.

"Note on a Disease affecting the Head and Eyes of Fish."—Prof. E. A. Birge.

"Kame Ridges and Gravel Trains within the Area of the Green Bay Glacier."—Prof. Ira M. Buell.

"British Convicts Shipped to British American Colonies."—Prof J. D. Butler.

Adjourned.

FRIDAY, 2 P. M.
ROOMS OF THE ACADEMY.

The treasurer's report was approved on the recommendation of the auditing committee.

The following papers were read:

"Sectional Features in American Politics."—H. J. Desmond.

"The Defective Classes." — A. O. Wright.

"The Science of the English Language in the Light of the Gothic." — G. H. Balg.

"Aristotle's Physics." — Rev. J. J. Elmendorf. (This paper was read by title and a brief synopsis of it given by Prof. Allen.)

Adjourned.

FRIDAY, 7:30 P. M.
ASSEMBLY CHAMBER.

The following papers were read.

"Recent Explorations of Aztalan Mounds, with a Discussion of the Pre-historic Races of America." — Rev. A. N. Somers.

"Studies in Archaeology." — Rev. S. D. Peet.

Prof. Van Hise offered the following resolution:

That a sufficient amount of money be appropriated to illustrate the next volume of the transactions of the academy; the amount to be determined by the president, secretary and treasurer.

Carried.

Nominating committee reported the following candidates who were elected:

Dominie Schuler, 473 15th Ave., Milwaukee.
Prof. Floyd Davis, Madison.
Rev. W. A. McAtee, Madison.
Rev. J. H. Crooker, Madison.

Resolved (Prof. Van Hise), That the librarian be authorized to prepare a catalogue of the library of the academy, spending a suitable amount of money for the purpose.

Adjourned *sine die.*

TWENTIETH REGULAR MEETING.

Rooms of the Academy.
Thursday, Dec. 26, 1889.

Owing to the death of Pres. Allen, Vice-president King occupied the chair.

Moved (Prof. Barnes) that a president be elected for the unexpired term.

Carried.

Prof. Birge was elected.

President Birge in the chair.

The report of the secretary was read and approved.

Report of treasurer read.

The vice-president appointed an auditing committee consisting of Messrs. Barnes and Blackstone.

On motion, Messrs. Tatlock and H. P. Armsby were transferred to the list of corresponding members.

The president appointed Profs. Bigham and King a committee on new members.

Adjourned.

Friday, 9:30 A. M.

President Birge in the chair.

Report of auditing committee was received and adopted.

The chair appointed Prof. J. D. Butler to prepare a memorial of Prof. Wm. F. Allen, Prof. T. C. Chamberlin to prepare a memorial of Prof. Roland D. Irving, and Rev. H. D. Maxson to prepare a memorial of Prof. Lucius Heritage, to be presented at the next regular meeting.

The following papers were read:

"The Chemical Constituents of Locust Bark."—F. B. Power and J. Cambier.

"Notes and a Query Concerning the Ericaceæ."—Chas. Chandler.

"Observed Discrepancies from Law of Attraction Reconciled and Certain Points of Astronomy Explained."—D. P. Blackstone.

It was moved and carried that Prof. C. O. Whitman be placed on the list of corresponding members.

The treasurer submitted a list of members many years in arrears.

Moved and carried that the names read be dropped.

Adjourned.

FRIDAY, 2:30 P. M.

Mr. A. J. Rogers in the chair.

The following papers were read:

"Kentucky Pioneers."—James D. Butler.

"Problems of Hypnotism."—Joseph Jastrow.

"On some Metamorphosed Eruptives in the Crystalline Rocks of Maryland."—Wm. H. Hobbs.

Adjourned.

FRIDAY, 8 P. M.

President Birge in the chair.

The committee on nominations reported the following names for membership.

Mr. Caleb N. Harrison, Milwaukee.
Prof. N. S. Fuller, Ripon.
Prof. A. A. Upham, State Normal School, Whitewater.
Prof. Chas. E. Bennett, Madison.
Dr. Wm. H. Hobbs, Madison.
Prof. C. P. Sennott, State Normal School, Milwaukee.

The Secretary was directed to cast the vote of the Academy for these persons.

The following papers were read:

"Science as Related to Invention."— A. J. Rogers.

"Some new Theories of the Greek perfect in Ka." — Chas. E. Bennett.

Moved and carried that the council be authorized to expend the amount necessary to meet the running expenses of the year.

Adjourned *sine die*.

GEO. W. PECKHAM,
Secretary.

TWENTY-FIRST REGULAR MEETING.

ROOMS OF THE ACADEMY,
TUESDAY, Dec. 30, 1890, 9 A. M.

President Birge in the chair.

Report of secretary read and approved.

In the absence of the treasurer, Hon. S. D. Hastings, Mr. F. W. McNair presented his report.

The president appointed Messrs. Van Hise and Barnes auditing committee on treasurer's report.

F. M. McNair read a list of members and the amounts due from each to date.

The following program was then followed:

"Recent Progress in the Chemistry of Sugars."— H. W. Hillyer.

"Some Observations on Lake Superior Stratigraphy."— C. R. Van Hise.

"Electro-Deposition of Aluminum in Aqueous Solutions." —A. J. Rogers.

"On Cleavage and Lamination in Gneisses and their Relation to Bedding."— Wm. H. Hobbs.

"The Eleventh Amendment to the Constitution."— C. H. Haskins. (Read by Prof. F. J. Turner.)

Adjourned.

TUESDAY, 2:30 P. M.

The auditing committee reported that the treasurer's report and vouchers had been examined and found to be correct. Signed C. R. Van Hise and C. R. Barnes.

On motion of Prof. Jastrow the report was approved.

The president appointed Pres. Chamberlin and Prof. Peckham a committee on new members.

The regular program was then resumed.

"Recent Theories of the Evolution of Sex."—A. N. Somers.

"Some Generalizations of Comparative Psychology."—Jos. Jastrow.

"Glacial Lobation in Ohio."—Frank Leverett.

"Recent Progress in Correlation and Differentiation of Glacial Deposits."—T. C. Chamberlin.

"Hypnotism."—A. N. Somers.

The committee on new members reported the following nominations:

Dr. C. H. Haskins, Madison.
Prof. E. S. Goff, Madison.
Prof. C. D. Marx, Madison.
Prof. A. A. Knowlton, Madison.
Prof. W. S. Leavenworth, Ripon.

On motion the secretary was instructed to cast the ballot of the Academy for these new members.

The meeting then adjourned.

TUESDAY, 7:30 P. M.

The academy listened to the address of Pres. E. A. Birge on "Recent Problems in Biology."

On the President's suggestion the usual formalities were waived and a very general discussion ensued.

The committee on nomination of officers reported as follows:

President, Prof. Geo. W. Peckham, Milwaukee.

Vice-president for Science, Prof. R. D. Salisbury, Beloit; vice-president for Letters, Rev. H. D. Maxson, Menomonie; vice-president of Arts, Prof. F. B. Power, Madison.

Treasurer, Hon. S. D. Hastings, Madison.

Secretary, Prof. C. E. Bennett, Madison.

Curator and librarian, Prof. Wm. H. Hobbs, Madison.

On motion the secretary was directed to cast the ballot of the Academy for the new officers.

It was moved and carried that the council be authorized to expend the amount of money necessary to meet the expenses of the ensuing year.

Adjourned *sine die.*

C. E. BENNETT,
Secretary.

NOTE — In June, 1891, the secretary, Prof. C. E. Bennett removed to Providence, R. I., and in September the president appointed Prof. Wm. H. Hobbs the secretary, *ad interim.*

TWENTY-SECOND REGULAR MEETING.

ROOMS OF THE ACADEMY.
TUESDAY, DEC. 29th, 1891.

Meeting called to order at 9:30 A. M.

Vice-president F. B. Power in the chair.

The report of the secretary was read and accepted.

The treasurer, Hon. S. D. Hastings, then read his report.

It was moved and carried that the following members be made honorary members of the Academy:

Prof. C. E. Bennett, Providence, R. I.
Mr. Ira M. Buell, Sun Prairie, Wis.
Prof. J. W. Stump, Oswego, N. Y.
Prof. C. D. Marx, Palo Alto, Cal.

The treasurer was given authority to drop from the list of members all who were in arrears more than three years.

The presiding officer appointed Prof. C. D. Marsh, Mr. Frank Leverett and Rev. A. N. Somers, a committee to audit the treasurer's report.

The report of the librarian and custodian was next read.

The librarian reported that the books of the library had been re-arranged and a card catalogue begun. He recommended to the Academy the appointment of a library committee of three, including the librarian, to consider means of enlarging the library and making it more accessible to members. It was further recommended that this committee be authorized to purchase from the funds of the Academy such odd volumes as may be necessary to complete the series of important journals.

It was moved by Prof. Van Hise to amend by requiring the expenditures of the committee to be subject to the approval of the council. Carried.

The recommendation was then adopted, and the presiding officer appointed Prof. G. L. Hendrickson and Prof. Geo. C. Comstock and the librarian, the library committee.

The custodian recommended that the collection of fossils belonging to the Academy be deposited in the collection of the University of Wisconsin to be stored by itself and labeled as the property of the Wisconsin Academy.

Prof. Birge moved that the recommendation be adopted subject to the acceptance of the university authorities.

Carried.

Prof. J. W. Stearns, in a brief address, reviewed the life of Rev. H. D. Maxson, the late vice-president of the Department of Letters, and paid a tribute to his many sterling qualities, to which Profs. Van Hise and Marsh added their testimony.

The president asked Prof. Stearns in the name of the Academy, to prepare a memorial of the life of Rev. Mr. Maxson for publication in the Transactions.

The president then appointed the following committees:

On Nominations of Officers — Profs. Van Hise, Birge and Hillyer.

On New Members — Profs. Birge, F. H. King and Turner.

On Publication — The Secretary *ex-officio* and Profs. Van Hise, Loomis and H. C. Tolman.

The literary program was then begun:

"Origin of the Iron Ores of the Lake Superior Region."— C. R. Van Hise, 25 minutes.

Discussed by Mr. Sennott.

"On New Attidae."— G. W. Peckham. (Read by title.)

"Notes on a Little Known Region of Northwestern Montana."— G. E. Culver, 25 minutes.

Discussed by Dr. Butler, Prof. Van Hise and Mr. Leverett.

"Some Influences of Sex on Personality."— A. N. Somers. (Read by title.)

"On the Limonene Group of Terpenes."— Edward Kremers. (Read by title.)

The meeting then adjourned till afternoon.

AFTERNOON SESSION, 2:30 P. M.

The auditing committee, through its chairman, Prof. Marsh, announced that the report and vouchers of the treasurer had been examined and found to be correct.

The program was then resumed.

"Notes on the Depth and Temperature of Green Lake." —C. Dwight Marsh.

"On the Deep Water Crustacea of Green Lake."—C. Dwight Marsh, 15 minutes.

Discussed by Profs. Birge and Van Hise.

"The Present Condition of the Latitude Problem."—G. C. Comstock, 30 minutes.

Discussion by Profs. Butler, Davies, Hoskins, Loomis and Van Hise.

"On Certain Analogies between the Theories of Elasticity and Electro-magnetism."—J. E. Davies, 25 minutes.

"On the Authenticity of the Commentariolum Petitionis of Quintus Cicero."—G. L. Hendrickson, 20 minutes.

"The effect of Changes of Temperature on the Distribution of Magnetism."—H. B. Loomis, 25 minutes.

The Academy adjourned till evening.

EVENING SESSION. 7:30 P. M.

The committee on New Members, through its chairman, Dr. Birge, nominated the following for membership, and the secretaty was instructed to cast the ballot of the Academy for them.

Prof. G. A. Tolbert, Racine.
Mr. Geo. E. Luther, U. S. G. S., Madison.
Prof. F. L. Van Cleef, Madison.
Prof. G. L. Hendrickson, Madison.
Dr. H. B. Loomis, Madison.
Prof. G. E. Culver, Madison.
Dr. A. H. Tolman, Ripon.
Mr. S. D. Townley, Madison.
Dr. Edward Kremers, Madison.

Dr. H. C. Tolman, Madison.
Dr. C. F. Hodge, Madison.
Prof. W. A. Eckels, Ripon.

The literary program was then resumed.

"On Some Interesting Pseudomorphs from the Taconic Region."— Wm. H. Hobbs, 10 minutes.

"On Cladocera of Madison, Wisconsin."— E. A. Birge, 30 minutes.

Discussion by Profs. Jastrow, Barnes and Marsh.

"Some New Points in the Physiology and Hygiene of Nerve Fatigue."— C. F. Hodge, 30 minutes.

Discussion by Prof. Jastrow.

"On the Correlation of Moraines and Raised Beaches of Lake Erie."— Frank Leverett, 30 minutes.

Meeting adjourned till next day.

WEDNESDAY, 9 A. M.

"The Council Houses and Clan Centres of the Effigy Builders."—Dr. S. D. Peet, 25 minutes. (Read by his son, Mr. C. E. Peet.)

Prof. Leverett then supplemented his paper of Tuesday evening which had been abridged owing to the lateness of the hour.

"On Two New Occurrences of Diabase."—G. E. Culver and Wm. H. Hobbs, 20 minutes.

"The Pseudo-Gregorian Drama *Χρίστος Πασχων* in its Relation to the Text of Euripides."—F. L. Van Cleef. (Read by title.)

"Early Lutheran Immigration to Wisconsin."—Kate A. Everest, 15 minutes. (Read by F. J. Turner.)

The Committee on Nomination of Officers through its chairman, Prof. Van Hise, nominated for vice-president of the Department of Letters, vice Rev. H. D. Maxson, deceased, Dr. A. H. Tolman of Ripon, and for secretary, vice Prof. C. E. Bennett removed to Providence, R. I., Dr. Wm. H. Hobbs of Madison.

The secretary was instructed to cast the ballot of the academy for these officers.

The program was then resumed.

"Clocks and Watches"—R. G. Norton, 8 minutes.

"Ponderable and Imponderable Fluids."— Simeon Mills, 10 minutes.

"Limited Distribution of the Waterloo Boulder Train."— Ira M. Buell.

Prof. Van Hise spoke of the desirability of holding a local meeting each year, at some of the educational centres of the state, in addition to the regular annual meeting held in Madison, and moved that the council be authorized to hold such a meeting before the next annual meeting making all necessary arrangements as to time and place. After discussion by the president, Prof. Marsh and others, the measure was carried unanimously.

On motion of the treasurer, Dr. A. L. Chapin of Beloit, was made a life member of the academy.

The meeting then adjourned *sine die*.

Wm. H. Hobbs,
Secretary.

REPORTS OF TREASURER.

MADISON, December 27, 1888.

To the Wisconsin Academy of Sciences, Arts and Letters.

GENTLEMEN: The undersigned would respectfully present the following statement of the financial transaction of the Academy during the past year: —

Balance on hand December 27, 1887	$849 19	
Received from members during the year for fees and dues	53 00	
Received from interest on permanent loan	40 00	
		$942 19

The disbursements have been as follows: —

1888.			
Jan. 21.	Paid Nelson & North for printing blank notices	$2 00	
June 4.	Paid Luding Kumlein for redrawing maps	10 00	
July 2.	Paid Moss Engraving Co. engraving plates	50 00	
Oct. 2.	Paid Marr & Richards, engraving maps	10 00	
Dec. 1.	Paid M. J. Cantwell for printing	7 75	79 75
	Balance on hand, Dec. 27, 1888		$862 44

Vouchers herewith submitted,

SAMUEL D. HASTINGS.
Treasurer.

To the Wisconsin Academy of Sciences, Arts and Letters:

GENTLEMEN: The following is a statement of the financial transactions of the Academy during the past year, viz.:

Balance on hand as per last statement	$862 44
Received for interest on, permanent fund	40 00
Received from members for initiation fees and annual dues	85 50
	$987 94

The disbursements on the order of the president and secretary have been as follows, viz.:

1879.			
Jan. 10.	Paid W. F. Allen on account of catalogues	$10 00	
Jan. 17.	Paid W. F. Allen on account of catalogues	12 40	
Jan. 18.	Paid Burdick, Armitage & Allen for printing	8 50	
Jan. 18.	Paid G. W. Peckham for postage and envelopes	2 65	
Mar.	Paid E. A. Birge for cash paid for catalogueing library	16 00	$49 55
	Balance on hand Dec. 26, 1889		$938.39

Respectfully submitted,
SAMUEL D. HASTINGS,
Vouchers herewith submitted. *Treasurer.*

MADISON, December 30, 1890.

To the Wisconsin Academy of Sciences, Arts and Letters:

GENTLEMEN: The following is a statement of the financial transactions of the Academy during the past year, viz.:

Balance on hand as per last statement	$938 39	
Received for interest on permanent fund	40 00	
Received from members for initiation fees and annual dues	88 00	$1,066 39

The disbursements on the order of the president and secretary have been as follows, viz.:

1889.			
Dec. 27.	Paid S. D. Hastings for postage and envelopes for 6 years	$15 50	
	Paid Geo. W. Peckham, postage, envelopes, etc	1 68	
Dec. 28.	Paid Burdick, Armitage & Allen, for printing	6 75	
1890.			
Feb. 3.	Paid E. A. Birge for postage, etc	27 00	
Feb. 18.	Paid Am. Express Co	6 75	
Mar. 7.	Paid Adams Express Co	3 95	
	Paid C. E. Hoyt for putting up documents	5 00	
Nov. 4.	Paid G. W. Peckham for bills of Moss Engraving Co., N. Y	30 10	
			$96 73
	Balance on hand Dec. 30, 1890		$969 66

Respectfully submitted,
SAMUEL D. HASTINGS,
Treasurer.

MADISON, December, 1891.

To the Wisconsin Academy of Sciences, Arts and Letters:

GENTLEMEN: The following is a statement of the financial transactions of the Academy during the past year:—viz.:

Balance on hand as per last statement	$969 66
Received for interest on permanent loan	40 00
Received from members for initation fees and annual dues	59 00
Total	$1,068 66

The disbursements upon the order of the president and secretary have been as follows, viz.:

1890.			
Oct. 30.	Paid L. S. Cheney for cataloging books, etc	$16 20	
1891.			
Jan. 31.	Paid A. C. McClurg & Co., printing, etc	4 35	
Feb. 21.	Paid Chas. E. Bennett, postage and express	1 75	
Mar. 4.	Paid Mrs. E. A. Birge, for express	1 00	
May 4.	Paid Burdick, Armitage & Allen for printing	3 50	
Aug. 6.	Paid State Journal, printing, etc	2 85	
Nov. 11.	Paid Detrich & Adams stamp pad, etc	75	
Nov. 11.	Paid Library Bureau (Boston), sundries	12 88	
Nov. 11.	Paid W. H. Hobbs, postage, express, etc	7 90	
	Total		$51 15
	Balance on hand —— 1891		$1,017 51

Respectfully submitted,

SAMUEL D. HASTINGS,

Treasurer.

REPORT OF THE LIBARIAN AND CUSTODIAN.

(*Presented at the Twenty-second Regular Meeting, December 29th,* 1891.)

The arrangement and cataloguing of the books of the library has been begun during the past year, and the catalogue is about a third completed. The work has been much hindered because access to the rooms can be had only on Saturdays and during vacations, owing to their being used for meetings of the law and history classes. The cases and shelves have been washed and the doors fitted with new locks where necessary. The cases have been given numbers from 1 to 31, and the shelves letters. The dust of ages has been removed from the books and a temporary arrangement made on the plan which follows.

As most members know, the library consists almost solely of journals obtained in exchange for the Transactions of the Academy. A primary classification has been made into: (1) Journals which treat of Sciences, Arts and Letters. (2) Journals restricted to Sciences. (3) Journals treating of special sciences, as biological journals, geological journals, etc. (This class contains a subdivision for each science or group of sciences represented.) (4) Journals relating solely to the Arts. (5) Journals relating to Letters. Supplementary to each of these divisions is a small collection of separate works and brochures of papers in other journals. The bulk of the library of the Academy is embraced in the first three divisions — general and scientific journals.

Under this primary grouping the journals are classified according to language, as English, German, French, Italian, Dutch, Norwegian, Swedish, Russian, etc.

A list showing this arrangement, with the number of cases where the journals of each department are to be found, will be posted this noon near the door, so that members can inspect the shelves and learn what journals the library possesses in each or any department of knowledge.

The card catalogue has been adopted as in every way the most convenient and the best adapted to any change of arrangement of books that may in future become necessary. (I should perhaps state that a partial card catalogue exists, but as it does not tell where the books are to be found, it proved easier to make a new one than to use the old one.) The present classification of the cards is the same as that of the books, and each card gives reference to number of case and letter of shelf where the book is to be fonnd. The books have been given numbers on the following plan: Each journal has a journal number, and each volume of that journal a volume number separated from the journal number by a space and period. The volume number is generally the number of the volume. This makes it convenient to number and catalogue accessions.

It is proposed, if possible, to finish the catalogue before spring and publish a list of the journals in volume viii of the Transactions.

The acknowledgment of books received and the details of the work of cataloguing have been carried out by Mr. L. S. Cheney, Fellow in Biology of the University of Wisconsin, who has been paid for the work. Credit is due him for the care he has exercised in a work requiring considerable care. Journals have in some cases been found bound with incorrect titles, parts of a volume bound with odd numbers left out, etc.

At the next annual meeting of the Academy I expect to be able to present a list of the most valuable of the journals, and the Academy will be asked to appropriate money for binding them.

As soon as the library is catalogued it will, I think, possess considerable value to many of the members as a library of reference. It includes many quite important journals. I would recommend to the Academy the appointment of a library committee of three, of whom the librarian shall be a member *ex-officio*, to consider means of increasing our list of exchanges, other means of enlarging and improving the library, and how it shall be made most accessible to members. The constitution provides that such a committee be appointed annually. I recommend that this committee be given authority to purchase—subject to the approval of the council—from the funds of the Academy odd volumes, when necessary to complete our series.

As custodian of the collection of specimens of the Academy, I have little to report. The value of the collection consists mainly in the type fossils of the late Wisconsin Geological Survey, whose space on the shelves is needed for the library. I recommend that these fossils be deposited in the collections of the University of Wisconsin where they can be stored by themselves, labelled as the property of the Wisconsin Academy, and be accessible for study. This would be done subject to the approval of the university authorities.*

Respectfully submitted,
WM. H. HOBBS,
Librarian and Custodian.

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*The recommendations in this report were favorably acted on by the Academy. (See proceedings, p. 412.) The work of the library committee is hardly more than begun, and a full report will be given at the next annual meeting. The action of the Academy on the second recommendation (concerning collection of fossils), has been presented to the faculty of the University of Wisconsin, and on their recommendation permission was given by the Board of Regents to transfer the collection to the university. The transfer has been made accordingly.—SECRETARY, April, 1892.

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Steele, Rev. G. M., Principal Wilbraham Seminary, Wilbraham, Mass.
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Tatlock, John, Jr., ——————.
Trelease, Prof. William, Washington University, St. Louis, Mo.
Trumbull, J. H., LL. D., Hartford, Ct.

Van de Warker, Eli, M. D., Syracuse, N. Y.
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Whitney, Prof. W. D., Yale University, New Haven, Ct.
Winchell, Prof. N. H., State Geologist, Minneapolis, Minn.

Young, Rev. A. A., Monona, Iowa.

NOTE.— The above list is believed to contain many errors. Note of corrections should be sent to the secretary.

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Jastrow, Prof. Joseph, Madison.

Kerr, Prof. Alexander, Madison.
King, Prof. F. H., Madison.
Knowlton, Prof. A. A., Madison.
Kremers, Prof. Edward, Madison.

Lamb, F. J., Madison.
Leverett, Frank, (U. S. Geol. Survey), Madison.
Leavenworth, Prof. W. S., Ripon.

Luther, Geo. E. (U. S. Geol. Survey), Madison.
Loomis, Prof. H. B., Madison.

Marks, Dr. Solon, Milwaukee.
Marsh, Prof. C. Dwight, Ripon.
Meacham, Dr. J. G., Sr., Racine.
Meacham, Dr. J. G., Jr., Racine.
Mills, Hon. Simeon, Madison.
McLangen, Chas., Milwaukee.
Morris, W. A. P., Madison.

Nader, Capt. John, Madison.
Norton, R. G., Madison.
Noyes, Hon. G. H., Milwaukee.

Orton, Hon. H. S., Madison.

Parkinson, Prof. J. B., Madison.
Peckham, Prof. Geo. W., Milwaukee.
Power, Prof. F. B., Madison.
Pray, Prof. T. B., Whitewater.
Puls, A. J., Milwaukee.
Pudor, Prof. C. C., Madison.

Rogers, Prof. A. J., Milwaukee.

Salisbury, Prof. R. D., Madison.
Schuler, Dominee, Milwaukee.
Sennott, Chas. P., Milwaukee.
Schneiding, Henry E., Racine.
Smith, Prof. E. G., Beloit.
Sprague, A. R., Milwaukee.

Thayer, Hon. J. B., Superior.
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Tolman, Prof. H. C., Madison.
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Tolbert, Prof. G. A., Racine.

Upham, Arthur A., Whitewater.

Van Cleef, Prof. F. L., Madison.
Van Hise, Prof. C. R., Madison.
Van Velzer, Prof. C. A., Madison.
Viebahn, Prof. C. F., Watertown.

Wheeler, Prof. W. M., Milwaukee.
Wright, Prof. A. O., Madison.

NOTE.—Members will accommodate the secretary by promptly informing him of any errors or omissions in the above list.

DECEASED MEMBERS.

Allen, W. C.
Allen, Prof. Wm. F., Prof. of History, University of Wisconsin.
Armitage, W. E., Right Rev. Bishop, P. E. Church, Milwaukee.

Carpenter, S. H., LL. D., Prof. of English Language, University of Wisconsin.
Case, J. I., Racine.
Conover, O. M., LL. D., Madison.

De Koven, S. T. D., Warden Racine College, Racine.
Dewey, Nelson.
Draper, L. C.
Dudley, Wm., Madison.

Eaton, J. H., Ph. D., Prof. of Chemistry, Beloit College.
Engelman, Peter, Director German and English Academy, Milwaukee.

Feuling, J. B., Ph. D., Prof. Philology, University of Wisconsin.

Hawley, C. T., Milwaukee.
Heritage, Lucius, Prof. of Latin, University of Wisconsin.
Holton, Hon. E. D., Milwaukee.

Irving, R. D., E. M., Ph. D., Prof. of Geology, University of Wisconsin, and U. S. Geologist.

Knapp, Hon. J. G., Milwaukee.
Kumlein, Thure.

Lapham, I. A., LL. D., State Geologist, Milwaukee.
Lawler, Hon. John.
Lewis, Mrs. H. M.
Little, Thomas H., Supt. Institution for the Blind, Janesville.

McDill, A. S., M. D., Supt. State Hospital for the Insane, Madison.

Nicodemus, W. J. L., A. M., C. E., Prof. of Engineering, University of Wisconsin.

Paul, Hon. Geo. H., Milwaukee.
Pradt, J. B.

Reed, George.

Smith, Wm.

Winchell, Prof. Alexander, University of Michigan, Ann Arbor, Mich.

In Memoriam.

Roland Duer Irving.

William Francis Allen.

Lucius Heritage.

Henry Doty Maxson.

[Courtesy of American Geologist.]

Roland D Irving

ROLAND DUER IRVING.

Former President of the Wisconsin Academy of Sciences, Arts and Letters.

By T. C. CHAMBERLIN,*

President of the University of Wisconsin.

Professor Irving was born in the city of New York, on the 29th day of April, 1847. His father, the Rev. Pierre P. Irving, was a clergyman of the Episcopal church and a nephew of Washington Irving. His mother was a daughter of Chief Justice John Duer, of the supreme court of New York. Sprung thus from a family of literary talent on the one side and of judicial on the other, Professor Irving inherited tastes and capabilities that especially fitted him for his subsequent work. His birth and early education in the metropolis of our country impressed upon him something of the breadth and complexity of its commercial, social and intellectual activities and gave to a mind naturally disposed to large and analytic conceptions a pronounced breadth and a discriminative habit. His youth was spent upon Staten Island, to which his father had removed in his second year. A lack of entire robustness of health, emphasized by frequent attacks of illness and a weakness of sight, interfered with systematic study and checked the indulgence of his passionate fondness of reading. His early training was therefore conducted mainly at home, his father and sisters being his chief instructors. It was only in his twelfth year that he entered school. His dominant studies were classical, but he was fortunate in falling under the instruction of a teacher whose frequent rambles with his pupils fostered a love for natural history. Young Roland became especially interested in the collection of the rocks and minerals that were accessible upon the island. The identification and classification of these may be looked upon as the initiation of his subsequent scientific studies. In 1863 he entered the classical course of Columbia college. Forced by the condition of his eyes to suspend his studies in his sophomore year, he spent six months in England, the impress of which in certain choices of language and methods of thought remained with him throughout

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* This Sketch was first published in the American Geologist for January, 1887.

his life. On his return he was able to resume studies, though it was necessary that the greater part of the texts should be read to him. This probably strengthened a memory naturally retentive and drove him to meditative and independent thought, since he was measurably cut off from indulgence in simple acquisition. A full course in the School of Mines, of Columbia College, gave him the technical foundation for his future work.

During two of his summer vacations he found employment and practical experience in the coal mines of Wiconisco, Penn. Soon after graduation he was appointed superintendent of the smelting works at Greenville, N. J. Following this he was employed during parts of two years upon the Ohio geological survey. His career thus far had lain chiefly in the line of technical work. From this he was turned aside in 1870 by a call to the department of geology, mineralogy and metallurgy in the University of Wisconsin, and from that time onward his activities took two parallel lines, instruction and investigation. As an instructor his work was characterized by thoroughness, by a masterly command of the subjects he taught, by clearness of presentation and a graphic and humorous exposition, by perfect candor and sincerity, by earnestness, devotion and indefatigable industry — a rare combination of qualities, which made him not only a singularly effective instructor, but a worthy leader in all those moral and manly influences which characterize the true teacher.

Professor Irving's first independent geological investigation consisted of the demonstration that the Baraboo quartzites of central Wisconsin are very much older than the adjacent upper Cambrian sandstone (Dikelocephalus horizon), which was at the time a battled question.* Shortly after he made similar investigations on the quartzites near Waterloo, Dodge Co., Wis.†

Upon the inauguration of the recent geological survey of Wisconsin (1873), Professor Irving was appointed one of the three commissioned assistant geologists and began his well-known investigations in that connection. During the first year he was assigned to the study of the Penokee iron range. He was here compelled, at the outset of his official career, to encounter unwarranted expectations raised by previous flattering opinions respecting the richness of the iron deposits given by incautious and inexpert explorers. His perfectly candid and unreserved report brought the usual reward of frankness and sincerity in the face of opposing desire, at first a storm of protest and of adverse

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*On the Age of the Quartzites, Schists and Conglomerates of Sauk Co., Wis., Am. Jour. Sci., Vol. III, Art. xv, p. 93. The same in Trans. of Wis. Acad. of Sci. Arts and Letters, Vol. II, pp. 107–119.

†Note on the Age of the Metamorphic Rocks of Portland, Dodge Co., Wis., Am. Jour. Sci., Vol. V, Art. xxxi, p. 282.

criticism, which even threatened the existence of the survey, later, a sullen acquiescence in the truth, and finally, an admiration for the correctness and the courage of the position taken and a diversion of enterprise from unprofitable into successful lines of exploitation. In the second and third years of the survey Professor Irving's field embraced the Paleozoic and Archæan strata of central Wisconsin. In the last years he returned to the Lake Superior field and laid the broader foundation upon which nearly all of his subsequent investigations were based. The results of his studies in this official relationship are recorded in the four volumes of the Reports of the Wisconsin Geological Survey (1873–1879). Meanwhile he had published several short articles in the American Journal of Science, the Transactions of the Wisconsin Academy, and elsewhere. Among these the more important are the "Age of the Copper-Bearing Rocks of Lake Superior and the Westward Continuation of the Lake Superior Synclinal."* "Some New Points in the Elementary Stratification of the Primordial and Cambrian Rocks of South Central Wisconsin."† "The Stratigraphy of the Huronian Series of Northern Wisconsin, and on the Equivalency of the Huronian of the Marquette and Penokee Districts."‡

In 1880 Professor Irving began those investigations upon the geology of the Lake Superior region for the United States government which continued until the time of his death. The first of these consisted of a comprehensive study of the copper-bearing series, the results of which he gathered into a monograph which perhaps stands as the best single expression of his work.§ This was the first approach to a unified and systematic discussion of this great formation occupying a tract of 40,000 square miles and embracing portions of Michigan, Wisconsin, Minnesota and Canada. Whatever differences of opinion may continue to exist concerning the interpretation of the debated phenomena, this must ever be recognized as a monument of industrious and able investigation and of candid and careful induction. Following these studies upon the copper-bearing series, Professor Irving took up in a correspondingly comprehensive manner, the investigation of the iron-bearing formations of the Lake Superior region and their correlation with each other and with the original Huronian of Canada. Upon this work he was engaged at the time of his death. He had in preparation and nearing completion a monograph upon the Penokee-Gogebic range and had well in hand a large amount of material relating to the Marquette, Menominee and Vermilion Lake series, as well as the original Huronian and Animike groups. His loss at this fruitful stage of his work, incal-

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* Am. Jour. Sci., Vol. VIII, Art. vii, p. 46, 1874.

† Am. Jour. Sci., Vol. IX, Art. vii, p 440, 1875.

‡ Am. Jour. Sci., Vol. XVII, Art. xlix, p. 393, 1879.

§ "Copper-Bearing Rocks of Lake Superior." Monograph V., U. S. Geol. Survey, 1883.

culable as it is, might have been still greater but for the fact that all his material passed into the hands of his co-laborer, Professor Van Hise, who is intimately familiar with his unwritten as well as written views.

Some of Doctor Irving's leading conclusions from his later studies were set forth in his presidential address before the Wisconsin Academy of Sciences, Arts and Letters, entitled "Divisibility of the Aarchæan in the Northwest,"* and more especially in the following very notable papers: "Preliminary Paper on an Investigation of the Archæan Formations of the Northwestern States,"† "On the Classification of the Early Cambrian and Pre-Cambrian Formations. A Brief Discussion of Principles; Illustrated by examples drawn mainly from the Lake Superior Region,"‡ "Origin of Ferruginous Schists and Iron Ores of the Lake Superior Region,"‖ "Is there a Huronian Group?"¶ and the introduction to Bulletin Number 62 of the U. S. Geological Survey, "On the Greenstones of the Menominee and Marquette Regions," by Dr. G. H. Williams.

During these later years in which he was chiefly engaged upon monographic studies, he published numerous special papers, among which the more important were, "On the Nature of the Induration of the St. Peter's and Potsdam Sandstones, and of certain Archæan Quartzites in Wisconsin,"* "Paramorphic Origin of the Hornblende of the Northwestern States,"† "On Secondary Enlargements of Mineral Fragments in Certain Rocks"‡ (jointly with Professor C. R. Van Hise), and "The Junction Between the Eastern Sandstone and the Keweenawan Series on Keweenaw Point"§ (jointly with President Chamberlin).

Professor Irving's greatest contributions to science lay in the department of structural geology and genetic petrography. His investigations upon the great copper and iron-bearing series and the adjacent formations of the Lake Superior region, constitute a contribution of the first order. The deep sympathy of the present writer with Professor Irving's views on questions that have been subjects of divergence of opinion should perhaps restrain him from a full expression of his appreciation of the profound value of this work, lest a color of personal partiality be thrown over this sketch, but it is not too much to assert that supporter and opponent alike recognize the ability which has characterized these investigations, and the high order of value which must attach to them whatever interpretations may finally prevail.

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* Am. Jour. Sci., Vol. XXIX, pp. 237-249, 1885.

† U. S. Geol. Survey, Fifth Annual Report, pp. 181-241, 1885.

‡ U. S. Geol. Survey, Seventh Annual Report, 1886.

‖ Am. Jour. Sci., Vol. XXXII, p. 255, 1886.

¶ Am. Jour. Sci., Vol. XXXIV, pp. 204-249, 1887.

* Am. Jour. Sci., Vol. XXV, p. 401, 1883.

† Am. Jour. Sci., Vol. XXVI, p. 321, 1883.

‡ U. S. Geol. Survey, Bulletin No. 8.

§ U. S. Geol. Survey, Bulletin No. 23.

In the line of petrographic genesis Professor Irving made two very notable contributions, first, the demonstration of the prevalence and importance of the secondary growth of certain fragmental constituents of clastic rocks and the crystallographic co-ordination of the additions with the nuclear particles. The existence of such a second growth in quartz grains was an earlier discovery of others but was hit upon by him independently. Jointly with his co-laborer, Professor Van Hise, he demonstrated a similar second growth of hornblende and other minerals and showed that such rebuilding was a prevalent process, constituting an important element in those changes heretofore designated metamorphic, thereby contributing an important factor in the elucidation of that mysterious process.

Perhaps the most important single determination by Professor Irving, and one of his latest, was the demonstration of the origin of the iron ores of the Lake Superior region. By a series of admirable investigations he traced step by step the transformation of the ores from original earthy carbonates of iron to their present forms, and made it altogether clear that they were primarily deposited as sediments in a manner closely similar to that of the iron ores of the Coal Measures. This discovery has given added significance to the association of these ores with carbonaceous shales, and has led to the recognition of the iron-bearing series as marking in some sense a pre-Cambrian carboniferous period.

The characteristics of Professor Irving as a scientific investigator and writer are too well known to the readers of this magazine to need analysis here. Personally, to those who came within the circle of his intimate acquaintance, he possessed rare charms of character.. Sincere, frank, conscientious in the highest degree, he was a warm and true friend. Possessed of a rollicking brusque humor, his intercourse was marked by a freshness that was a source of constant enjoyment and attraction to his intimate associates. No phrase better expresses it than picturesqueness. Modest and retiring, the number of his close friends was not large but their attachment to him was strong. The full strength of these attachments has only been realized in their breaking.

He leaves a wife, a daughter and two sons. The artistic skill of Mrs. Irving appears in some of the sketches and particularly in many of the microscopic illustrations of her husband's works.

William F. Allen

WILLIAM FRANCIS ALLEN.

Late President of the Wisconsin Academy of Sciences, Arts and Letters.

By JAMES D. BUTLER.

William Francis Allen was born September 5, 1830, and died December 9, 1889. His birth was in Northborough, a Massachusetts village, thirty-five miles from Boston; his death was in Madison. He graduated at Harvard University in 1851. His preparation for college was made at home in a school taught by his father, also a Harvard graduate, and a Unitarian pastor. For three years he gave instruction at New York city in a private family, and then in 1854 went abroad. He was for one year a student in the universities of Berlin and Göttingen. The following winter he spent in Rome, and the spring in Greece, returning to America in June, 1856. During the next seven years he was one of the principals of a classical school near Boston, at West Newton. Late in 1863, accompanied by his wife, married the year before, he went to South Carolina in the employ of the Freedman's Aid Association. After a half year of pioneer work in the education of negroes he came north, but very soon repaired to Arkansas as an agent of the Sanitary commission. This service was over early in 1865, and in the spring he returned to South Carolina, where he served till the close of the school year as a superintendent in Charleston. The next two years he taught, first in Antioch college, Ohio, and then at a military academy in New Jersey. His first wife died in 1865, and after three years he re-married.

Professor Allen was a religious man. He was the true founder of the Unitarian church in Madison. His life was a sermon of admonition and a hymn of praise. The training of his children, a daughter by the first marriage and three sons by the second, was a rare specimen of personal assiduity. His nature was so far from doing harms that he suspected none, and his faith in the doctrine of depravity may hence not have been orthodox. Notwithstanding, no more stinging censure smote Fisk and Tweed than fell from his lips.

His coming to Wisconsin was in 1867. In that year he accepted a call to the state university. His chair was at first called that of Ancient Languages and History, afterwards Latin and History, and for the last four years of his life History alone. In this Northwest he found the niche he was ordained to fill — for his teachings here his whole past life, studies at home and abroad, early training and varied school experiences — proved an admirable preparation. How well he paid for more than a score of years the educational debt due to his profession it is needless to say. Witnesses abound on every side. They agree that he gave much information, but that in a way which inspired more than it informed. It was a favorite maxim with Prof. Allen that "moral education cannot be absent from any living system, that the only foundation of thoroughness in study is that virtue which embraces a larger share of human duties within its definition than any other — faithfulness." Exemplifying in himself the virtue he praised, he became an inspiration to many a student — filling him with a life-long delight in whatsoever things are true, honest, just, pure, lovely, virtuous and praiseworthy. Seeing him always an eager learner, his pupils became themselves the more eager to learn.

While faithful to all details of his instructional routine, Prof. Allen was a voluminous author. The bibliography of his writings, in his Memorial volume, fills thirty pages and comprises more than nine hundred articles. We do not wonder that the number is multitudinous, for many of the articles were brief, so much as at their diversified nature; titles are arranged under thirty specific heads, but some of them find their proper place only under yet another division styled Miscellaneous. Before we run our eyes over a tithe of the topics we feel that the author, who never wrote on a subject he had not investigated, was a multifarious scholar — a rare survival of what former generations called a polymathist. We are surprised that he, a recluse scholar, touched society at so many points. He treated of slave songs and the negro dialect, and of Latin grammar as well — now of Aristophanes and then of Uncle Remus — here of the snake dance in Arizona, and anon of a day with a Roman gentleman. He drew each change of many-colored life.

After all, our feeling is that Prof. Allen was first, last and chiefly an *historian.* A great majority of his papers, whether in periodicals, or the Madison Literary Club or in our Academy, were historical. If he wrote upon Shakespeare his themes were the historical plays. If his theme was Novels, it was historical fiction. His twenty lectures in Johns Hopkins University were historic. His editions of classics were mainly historical authors. Whatever the subject that came before him his view of it was historic. Every fact in his mind, if past, had made history; if present, was making history, and if future, was about to make history. Thus, through its relations, and thus only had any fact value for him. All were but parts of a stupendous whole.

From Prof. Allen's early sojourn in Rome as well as the nature of his academic and university teaching, Roman history became predominant in his thoughts, studies and writings. A hundred of his published articles on as many aspects of this vast department each shed some side light upon it. His editions of Cæsar and Tacitus, with notes upon them, his classes in Sallust and Livy equipped him fully for writing with classic taste and terseness his own *Short History of the Roman People*, the crowning key-stone in the arch of his authorship — in penning the last line of which he ceased at once to work and live. Nay, rather, he still lives, for we are instinctively prompted to apply to him the touching words which he taught, edited, and loved so well: *Quicquid ex Agricola amavimus, quicquid mirati sumus, manet, mansurumque est in animis hominum.*

LUCIUS HERITAGE.

By HENRY DOTY MAXSON.

Lucius Heritage, son of Isaac C. and Margaret S. Heritage, was born Dec. 21, 1848, in Walworth, Wisconsin. In childhood his family removed to Milton, where he spent a large portion of his life. The death of his mother in 1864, led to a suspension of his studies and a temporary abandonment of his purpose to prepare himself for a profession. He accordingly became apprenticed to learn the wagon-maker's trade, and spent three years in this employment. His native taste for the things of the intellect led him, however, to embrace an opportunity to resume his studies, and he entered Milton College in 1869. Completing the Teacher's Course in that institution in 1872, he taught Latin for a short time in the St. Paul High School, and then returned to Milton to receive his diploma from the Classical Course, in 1875. In the fall of that year he became first assistant of Mr. Albert Markman, in the Milwaukee Academy, where he remained one year. It was my fortune after an interval of several years to succeed him in this position, and I found his reputation for character and scholarship still very vivid in the traditions of the school. He was pretty uniformly Mr. Markham's standard of comparison in speaking of the qualifications of a teacher. "As good a man as Heritage," was the highest compliment. In the fall of 1876 he sailed for Germany, where he spent a little over two years as a student in Göttingen, Halle and Leipsic. In the year after his return he was married to Miss Ruth G. Maxson, who survives him, with one son, their only child, born in 1885. It was during his temporary residence in Milton in 1879, that I first knew him. Our acquaintances are usually many; but the circle of friends who really enter the current of our life and make vital contributions to our character and thought, must always be small. It was my fortune from this time until his death, to number Prof. Heritage among these companions of the soul. In 1879 he was appointed Latin tutor in the University of Wisconsin. Prof. W. F. Allen, who, but for his untimely death, would have prepared a worthier biography than I am able to furnish, wrote soon after the death of Mr. Heritage that when he became a candidate for the instructorship in Latin, the University faculty were already predisposed in his favor on account of the way in which he acquitted himself at an inter-state oratorical contest held in Madison some years before. "I remember nothing about the contestants or their subjects," says Prof. Allen, "except that the delegate from Milton College attracted our attention by his intellectual countenance and fine bearing." In 1882, he was elected Assistant Professor of Latin, and four years later was placed in full charge of the department. In 1883-4 he spent another year in Germany, for the purpose of pursuing some special studies. Throughout his life he was a hard worker at whatever he undertook. Never robust, he undoubtedly overtaxed his strength by intense application to his studies. For several years, though he himself displayed great confidence and courage, his immediate friends had been solicitous about his health; and when a threatened attack of pneumonia prostrated him in November, 1888, they feared that the end was not far off. He rallied, however, and for a short time resumed his work in the University, but was soon compelled to relinquish it, and started on a Southern trip in the hope of regaining his health. The effort was fruitless. He died in Redlands, California, May 14, 1889.

Prof. Heritage wrote very little for publication. His most important literary work was an edition of the Dialogues of Tacitus, which, at the time of his death, he had been for some years engaged in preparing.

It seldom happens that the *nil nisi verum* of the biographer becomes more nearly one with the *nil nisi bonum* of the eulogist than in the case of Mr. Heritage. Of an exceptionally keen and accurate mind, he was no less distinguished for the integrity of his character.

His work as a pupil and a teacher I know only at second hand. Of the latter Prof. Allen wrote: "Under his charge the Latin department has advanced steadily in thoroughness and breadth of training. As every year I have taken some of the higher classes in Latin, I have noticed a marked improvement from year to year in the quality of the scholarship, especially in the capacity of ready and correct translation. His power as a teacher was very great. He won the affection and confidence of his classes in the highest degree, and was as distinguished for firmness and strictness as for courtesy and fairness."

While capable of making a thoroughly creditable appearance in public, and always holding the attention of his hearers by his clearness in both thought and expression, he did not seek publicity. He was essentially a man of the study. The energy, which with many gifted people largely spends itself in more ostentatious ways, with him was rather employed in enlarging and refining his personal culture. And thus the informal contacts of intimate friendship became a source of keen delight. It was in this phase of his life that I knew him best. Conversation with him was always enriching. He approached a question not in the role of a debater, but of an inquirer. As far as the interests of truth are concerned, debate is for those directly engaged in it worse than profitless, and it was repugnant to his temper. He was naturally restrained from taking the attitude of the advocate both by the judicialness of his mind and the candor of his character; and this disposition was powerfully reenforced by a discriminating intellect which refused to ignore identities or confuse distinctions. Add the command of a copious and precise vocabulary, and his equipment for enjoyable and instructive conversation was complete. It was almost a luxury to have him occasionally hesitate for a word. It gave one a moment to enjoy in anticipation the right word which was sure to come.

While by nature a man of the study, he by no means lacked interest in matters of public concern, and the interest was of a decidedly practical rather than of a merely academic character. Politics he greatly enjoyed, not at all as a trade, nor yet merely as a science, but more still as a field for effort in the line of promoting, or trying to promote, the common good. While he could never become a partisan, he was always anxious to actively identify himself with any organized effort to reform or purify our public life. The temperance problem and other social questions of importance in our day provoked earnest study, and when the line of action seemed clear, enthusiastic devotion. If he ever seemed to any one lacking in public participation in reformatory work, that fact must be set down to the impartiality of his mind, which insisted on seeing both sides of the shield; and that impartiality was greatly strengthened by an alert and delicate sense of humor—a quality of great service, not only in giving sparkle to speech, but also in restraining from absurdity. *In medio tutissimius ibis* was not with him the maxim of a calculating prudence. It rather represented the native temper of the man.

Of those deeper and more difficult themes which we call religious, we spoke frequently and freely. Mr. Heritage shrank from no light which the most thorough-going rationalism could shed on the problems of life. But through all this unrestrained communion of thought and inquiry, I never found his faith to falter in the underlying sanity of things, the eternal purpose which runs through all, and gives to human effort and character an immortal meaning. That purpose was most beautifully displayed in his life. We may well believe that, though not fully revealed to our eyes, that purpose has with no less beauty, been working itself out in his death.

H. D. MAXSON.

BY PROF. J. W. STEARNS.

Rev. Henry Doty Maxson, vice-president of the Wisconsin Academy of Sciences, died suddenly at Eau Claire, Nov. 23, 1891. His connection with the Academy had not been long, but the transparent sincerity of the man and his complete devotion to the highest aims, had made a strong impression upon its members. Mr. Maxson was born in De Ruyter, New York, of Seventh Day Baptist family, and the wish of his parents, and his own early choice, destined him for the ministry in that denomination. Accordingly, he was in due time sent to the denominational college, at Alfred, N. Y., to commence his preparation. But before the end of his first year a great change had gradually taken place in his convictions; and he acted upon it with the frankness which always characterized him, by renouncing his cherished plans and returning to his home. I have heard him relate with much emotion the struggle it cost him to take this step, because of the pain which he knew it would cause his mother. It seemed to separate him from his parents, and to cut off for the present the hope of a college education, of which he was very desirous. Fortunately these results which he dreaded did not follow, and in due time he graduated, in 1877, from Amherst college. He took the lead of his class in college. He was not only at the head of it in scholarship, but also in character, a marked man to whom his classmates looked with affectionate esteem and almost with reverence. He came to Wisconsin as a teacher, and was employed first at Milton college, then at Markham's Academy, in Milwaukee, and afterward for nearly five years as Institute conductor for the State Normal School at Whitewater. This service brought him into connection with a large body of young people upon whom his influence was strong and inspiring. His genial manners, and his kindly interest in them and their pursuits made warm personal friends of his pupils. He stood before them a refined gentleman, of quick sympathies, thorough scholarship, and lofty aims, and they were broadened and uplifted by the intercourse with him. In the spring of 1888 he became pastor of the Unitarian church at Menomonie. Here he accomplished remarkable results in a very short time. The magnetism of the man was quickly felt, and drew about him a strong following; and Bible classes, a kindergarten, a gymnasium, a literary society, a public library, arose and flourished under his inspiration. Mr. Maxson was an untiring worker for the broadening of human life and the refining of human nature. Although a close student himself, there was nothing of the recluse about him. On the contrary, he adapted himself with a sure insight to men of the most diverse types, and enjoyed deeply the opportunities of service to others which his position offered him. Thus in a brief life-time he was enabled to accomplish a notable work. Members of this society are familiar with his characteristics as a public speaker. His direct and truth-loving nature shone out in his discourse. You felt that a strong, sincere, cultured man was talking to you, and talking directly to the point, with a true insight and a large charity. He captivated you with the many-sidedness of his thought and the abundance of the resources from which it was illustrated and enforced. Those who had but a slight acquaintance with him felt the charm of his character, while those who enjoyed his intimacy found in him the best inspirations of a noble manhood.

AUTHORS' INDEX

APPENDIX.

APPENDIX.

List of Societies, Institutions, etc., with which the Wisconsin Academy Exchanges Publications.

An * indicates that the society has been recently placed on list.

Argentine Republic —

Buenos Ayres. Oficina Meteorologica Argentina.

Cordoba. Academia Nacional de Ciencias en Cordoba.

Australia —

Sydney. (New South Wales.) Department of Mines.

Austria —

Brieg. (Silesia.) Naturforschende Gesellschaft.

Graz. (Styria.) Naturwissenschaftliche Verein für Steiermark.

Görlitz. (Silesia.) Naturforschende Gesellschaft.

Prag. (Bohemia.) Die königl. böhmische Gesellschaft der Wissenschaften.

Vienna. K. k. Akademie der Wissenschaften.

Zoologisch-Botanische Gesellschaft.

K. Akademie d. Wissenschaften.

K. k. Naturhistorisches Hofmuseum.

*K. k. Geologische Reichsanstalt.

Belgium —

Brussels. Société Royale Malacologique.

Liege. Société Royale des Sciences

Mons. Société des Sciences des Arts, et des Letters du Hainaut.

Brazil —

Rio Janeiro. Museu Nacional do Rio de Janeiro.

Instituto Historico e Geographico Brazileiro.

Canada —

Halifax. (Nova Scotia.) Nova Scotia Institute of Natural Sciences.

Hamilton. Hamilton Association.

Montreal. Natural History Society. (The Canadian Record of Science.)

Ottawa. Ottawa Normal School. "The Ottawa Naturalist."

Toronto. The Canadian Institute.

Chili —

Santiago. Deutsche Wissenschaftliche Verein.

China—Continued.
Observatorio Astronómico.
Oficina Central Meteorolojica de Chile.

Denmark —
Copenhagen. Kongelige Danske Videnskabernes Selskabs.

England —
London. Bernard Quaritch, 15 Piccadilly W., London, England.
British Museum.
The Royal Society.
Manchester. Manchester Literary and Philosophical Society.
Newcastle-upon-Tyne. North of England Institute of Mining and Mechanical Engineers.

Finland —
Helsingfors. Sociéte des Sciences de Finlande.
Finska Vetenskaps-Societetens.
Observatoire Magnétique et Météorologique.
Finska Vetenskabs-Societeten.

France —
Amiens. Société Linnéenne du Nord de la France.
Bordeaux. Académie Imperiale des Sciences, Belles Lettres et Arts.
Caen. L'Académie Nationale des Sciences, Arts et Belles-Lettres.
Dijon. Academie des Sciences, Arts et Belles Lettres.

France—Continued.
Le Mans. Société d'Agriculture, Sciences et Arts de la Sarthe.
Lyon. Académie des Sciences, Belles Lettres et Arts.
Montpellier. Académie des Sciences et Lettres.
Paris. Annuaire Geologique Universel (M. M. Carez et Douvillé, 15 Rue de Tournon).
Rouen. Société des Amis des Sciences Naturelles.

Germany —
Bamberg. Naturforschende Gesellschaft.
Berlin. *Deutsche geologische Gesellschaft.
Kaiserliche Gesundheitsamte.
Zeitschrift der Gesammten Naturwissenschaften.
Bonn. Naturhistorische Verein der Preussischen Rheinlande u. Westfalens.
Bremen. Naturwissenschaftliche Verein.
Braunschweig. Verein für Naturwissenschaft.
Brünn. Naturforschende Verein.
Cassel. *Verein für Naturkunde.
*Realschule.
Danzig. Naturforschende Gesellschaft.
Dresden. Die Naturwissenschaftliche Gesellschaft Isis.
Elberfeld. Naturwissenschaftliche Verein in Elberfeld.
Emden. (Friesland.) Naturforschende Gesellschaft.
Frankfurt a.M. Physikalische Verein.

Germany—Continued.

Freiburg. Naturforschende Gesellschaft.

Geissen. Oberhessische Gesellschaft.

Göttingen. Kgl. Gesellschaft der Wissenschaften.

Halle. (Prussia.) Zeitschrift für Naturwissenschaften. (Dr. O. Luedecke.)

Kaiserliche Leopoldino-Carolinische deutsche Akademie der Naturforscher.

Heidelberg. Naturhistorisch-Medizinsche Verein.

Jena. *University of Jena.

Medicinisch-Naturwissenschaftliche Gesellschaft.

Kiel. University of Kiel.

Königsberg. *University of Königsberg.

Leipzig. (Saxony.) Verein für Erdkunde.

Magdeburg. *Naturwissenschaftliche Verein zu Magdeburg.

Mannheim. Verein für Naturkunde.

Metz. L'Academie de Metz.

Munich. K. b. Akademie der Wissenschaften.

Königliche Sternwarte.

Nassau. Nassauische Verein.

Nürnberg. Naturhistorische Gesellschaft.

Regensburg. (Bavaria.) Naturwissenschaftliche Verein zu Regensburg.

Historische Verein von Oberpfalz und Regensburg.

Strassburg. *Kaiserliche Universitäts- u. Landes-Bibliothek.

Wiesbaden. Nassauische Verein für Naturkunde.

Holland —

Amsterdam. Koninklijke Akademie van Wetenschappen.

's-Gravenhage. Nederlandsche Maatschappij ter Bevordering van Nijverheid.

Haarlem. Musée Teyler.

*Société Hollandaise des Sciences à Haarlem.

Rotterdam. Bataafsch Genootschap der Proefondervindelijke Wijsbegeerte.

Utrecht. Provinciaal Utrechtsch Genootschap van Kunsten Wetenschappen.

Koninklijk Nederlandsch Meteorologisch Institut.

Hungary —

Budapest. Bureau of Statistics of the Capital City Budapest.

Ireland —

Dublin. Royal Irish Academy.

Royal Dublin Society.

Italy —

Bologna. Instituto di Bologna.

Catania. Accademia Giœnia di Scienze Naturali in Catania

Florence. R. Institute di Studi Superiori Practici e di Perfezronamento.

Biblioteca Nazionale Centrale di Firenze.

Milan. Reale Instituto Lombardo di Scienze e Lettere.

Modena. Societa dei Naturalisti.

Regia Accademia di Scienze Lettere ed Arti.

Italy—Continued.

Naples. L'Anomalo (Doctor Angelo Zuccarelli, Via Salvator Rosa No. 38).
  Società Italiana delle Scienze.
  *Società di Naturalisti in Napoli.
Palermo. (Sicily) Reale Accademia di Scienze, Lettere e Belle Arti di Palermo.
Pisa. Società Toscana di Scienzi Naturali.
Rome. Ministero della Pubblica Istruzione.
  Comitato Geologico d'Italia.

Java —

Batavia. Königliche Verein fur Naturkunde (Koninklijke Natuurkundige Vereinigung).

Mexico —

Mexico. Sociedad de Geografia Y Estadistica de la Republica Mexicana.
  Museo Nacional.
  Sociedad Mexicana de Historia Natural.
  Sociedad Cientifica "Antonio Alzate."
Tacubaya. Observatorio Astronómico Nacional de Tacubaya.

Norway —

Bergen. Bergen Museum.
Christiana. Norwegian Meteorological Institute.
  Norske Gradmaalingskommission.
  Videnskabs Selskabet i Christiania.
  University of Christiania.

Portugal —

Lisbon. Academia Real das Sciencias de Lisbon.

Russia —

Kharkow. Société des Naturalistes à l'Université Imperiale de Kharkou.
Moscow. Société Impériale des Naturalistes de Moscou.
Meteorologisches Observatorium der Landwirthschaftlichen Akademie.
Odessa. * Club Alpin de Crimée (M. le prof. Kamienski, Sec'y. Odessa, Russia.)
St. Petersburg. Royal Free Economical Society of St. Petersburg.
  Comité Géologique.
  Acti Horti Petropolitani.
  Royal Academy of Sciences.
  Physikalisches Central-Observatorium.

Scotland —

Edinburgh. Royal Society of Edinburgh.

Spain —

Barcelona.* Real Academia de Ciencias Y Artes de Barcelona.
Madrid. Real Academia de la Historia.

Sweden —

Lund. University of Lund.
Stockholm. Kongliga Svenska Vetenskaps Akademiens.
  Kongl. Vitterhets Historie och Antigvitets Akademiens Manadsblad.

Sweden—Continued.

Upsala. University of Upsala.
Royal Society of Science.

Switzerland—

Basel. Naturforschende Gesellschaft.
Berne. Schweizerische Naturforschende Gesellschaft.
Frauenfeld. Thurgauische Naturforschende Gesellschaft.
Freibourg. Société Fribourgeoise des Sciences Naturelles.
Lausanne. Société Vaudoise des Sciences Naturelles.
Neuchatel. Société des Sciences Naturelles.
St. Gallen. St. Gallische Natur wissenschaftliche Gesellschaft.
Zürich. Naturforschende Gesellschaft.
Schweitzerische botanische Gesellschaft.

United States—

ARKANSAS:

Little Rock. * Geological Survey of Arkansas.

CALIFORNIA:

Berkeley. Agricultural Experiment Station of University of California.
Sacramento. California State Mining Bureau. Wm. Irelan, Jr., State Mineralogist.
San Diego. "The West American Scientist."
San Francisco. California Academy of Sciences.
San José. Lick Observatory.

United States—Continued.

COLORADO:

Colorado Springs. *Colorado College Scientific Society.
Denver. The Colorado Scientific Society.
Golden. State School of Mines.

DISTRICT OF COLUMBIA:

Washington. U. S. Naval Observatory.
U. S. Geological Survey. J. W. Powell, Director.
Library of War Department.
*National Geographic Society.
Smithsonian Institution.
Bureau of Education.
The American Monthly Microscopical Journal.
Weather Bureau, Dep't of Agriculture.
U. S. National Museum.

ILLINOIS:

Avon. The American Antiquarian and Oriental Journal, edited by Stephen D. Peet.
Champaign. Illinois State Laboratory of Natural History.
Springfield. *Geological Survey of Illinois.

INDIANA:

Brookville. *Indiana Academy of Science.
Indianapolis. *Geological Survey of Indiana.

IOWA:

Des Moines. Iowa Academy of Sciences.

KANSAS:

Topeka. The Kansas Academy of Sciences.

United States—Continued.

MARYLAND:

Baltimore. Johns Hopkins University.

MASSACHUSETTS:

Boston. Boston Society of Natural History.

*Massachusetts Institute of Technology.

American Academy of Arts and Sciences.

Cambridge. (Harvard Univ.) Museum of Comparative Zoölogy.

*Harvard University Library.

Salem. The American Association for the Advancement of Science.

Worcester. *American Antiquarian Society.

MICHIGAN:

Lansing. *Geological Survey of Michigan.

MINNESOTA:

Minneapolis. Geological Survey of Minnesota.

Minneapolis. Minnesota Academy of Natural Sciences.

MISSOURI:

Jefferson City. *Geological Survey of Missouri.

St. Louis. Missouri Botanical Garden.

The Academy of Sciences of St. Louis.

Kansas City. "Kansas City Review of Science and Industry."

NEBRASKA:

Lincoln. University of Nebraska.

United States—Continued.

NEW JERSEY:

Trenton. The Trenton Natural History Society.

Princeton. *Museum of Geology and Archæology of Princeton College.

NEW YORK:

Albany. New York State Museum of Natural History.

New York State Library.

University of the State of New York.

New York. Torrey Botanical Club.

*The Auk; A Quarterly Journal of Ornithology.

American Museum of Natural History. (Central Park.)

New York Microscopical Society.

*American Geographical Society.

*The Technical Index.

Linnæan Society.

NORTH CAROLINA:

Chapel Hill. *Geological Survey of North Carolina.

The Elisha Mitchell Scientific Society.

OHIO:

Cincinnati. Cincinnati Society of Natural History.

Cleveland. Cleveland Academy of Natural Sciences.

Columbus. Ohio Agricultural Experiment Station.

Geological Survey of Ohio.

Granville. *Journal of Comparative Neurology. (C. L. Herrick, Editor.)

United States—Continued.

Ohio:

Granville. * Bulletin of the Scientific Laboratories of Denison University. (W. G. Tight, M. S., Editor.)

Pennsylvania:

Harrisburg. Second Geological Survey of Pennsylvania.

Philadelphia. Academy of Natural Sciences.

* The American Naturalist.

Zoological Society of Philadelphia.

State College. (Center County.) The Pennsylvania State College Agricultural Experiment Station.

United States—Continued.

Texas:

Austin. * Geological Survey of Texas.

West Virginia:

* Morgantown. West Virginia University.

Wisconsin:

Madison. Agricultural Experiment Station of University of Wisconsin.

State Historical Society.

University of Wisconsin.

Washburn Observatory of University of Wisconsin.

Milwaukee. Naturhistorische Verein von Wisconsin.

The following Colleges and Incorporated Academies of the state are entitled to receive the Transactions of the Academy:

Northwestern University, Watertown.
Milwaukee Academy, Milwaukee.
University of Wisconsin, Madison.
Ecclesiastical College of St. Lawrence, Mt. Calvary, Fond du Lac County.
Carroll College, Waukesha.
Pio Nono College, St. Francis, Milwaukee County.
Sacred Heart College, Watertown.
Lawrence University, Appleton.
Beloit College, Beloit.
Yale College, Galesville.
Concordia College, Milwaukee.
Ripon College, Ripon.
German English Academy, Milwaukee.
Nashota House, Nashota.

The Public Libraries of the following places in the state are entitled to receive the Transactions of the Academy:

Ashland,
Beaver Dam,
Eau Claire,
Fond du Lac,
Green Bay,
Janesville,
La Crosse,
Madison,
Manitowoc,
Marinette,
Menominee,
Merrill,
Milwaukee,
Neenah,
Sparta,
Superior,
Tomahawk,
Waupun.

CHARTER.

AN ACT TO INCORPORATE THE "WISCONSIN ACADEMY OF SCIENCES, ARTS AND LETTERS."

The people of the State of Wisconsin, represented in senate and assembly, do enact as follows:

Section 1. Lucius Fairchild, Nelson Dewey, John W. Hoyt, Increase A. Lapham, Alexander Mitchell, Wm. Pitt Lynde, Joseph Hobbins, E. B. Wolcott, Solon Marks, R. Z. Mason, G. M. Steele, T. C. Chamberlin, James H. Eaton, A. L. Chapin, Samuel Fallows, Charles Preuser, Wm. E. Smith, J. C. Foye, Wm. Dudley, P. Englemann, A. S. McDill, John Murrish, Geo. P. Delaplaine, J. G. Knapp, S. V. Shipman, Edward D. Holton, P. R. Hoy, Thaddeus C. Pound, Charles E. Bross, Lyman C. Draper, John A. Byrne, O. R. Smith, J. M. Bingham, Henry Bætz, Ll. Breese, Thos. S. Allen, S. S. Barlow, Chas. R. Gill, C. L. Harris, George Reed, J. G. Thorp, William Wilson, Samuel D. Hastings and D. A. Baldwin, at present being members and officers of an association known as "The Wisconsin Academy of Sciences, Arts and Letters," located at the city of Madison, together with their future associates and successors forever, are hereby created a body corporate by the name and style of the "Wisconsin Academy of Sciences, Arts and Letters," and by that name shall have perpetual succession; shall be capable in law of contracting and being contracted with, of suing and being sued, of pleading and being impleaded in all courts of competent jurisdiction; and may do and perform such acts as are usually performed by like corporate bodies.

Section 2. The general objects of the Academy shall be to encourage investigation and disseminate correct views in the various departments of science, literature and the arts. Among the specific objects of the Academy shall be embraced the following:

1. Researches and investigations in the various departments of the material, metaphysical, ethical, ethnological and social sciences.

2. A progressive and thorough scientific survey of the state, with a view of determining its mineral, agricultural and other resources.

3. The advancement of the useful arts, through the applications of science, and by the encouragement of original invention.

4. The encouragement of the fine arts, by means of honors and prizes awarded to artists for original works of superior merit.

5. The formation of scientific, economical and art museums.

6. The encouragement of philological and historical research, the collection and preservation of historic records, and the formation of a general library.

7. The diffusion of knowledge by the publication of original contributions to science, literature and the arts.

SECTION 3. Said Academy may have a common seal and alter the same at pleasure; may ordain and enforce such constitution, regulations and by-laws as may be necessary, and alter the same at pleasure; may receive and hold real and personal property, and may use and dispose of the same at pleasure; *provided*, that it shall not divert any donation or bequest from the uses and objects proposed by the donor, and that none of the property acquired by it shall, in any manner, be alienated other than in the way of an exchange of duplicate specimens, books, and other effects, with similar institutions and in the manner specified in the next section of this act, without the consent of the legislature.

SECTION 4. It shall be the duty of the said Academy, so far as the same may be done without detriment to its own collections, to furnish, at the discretion of its officers, duplicate typical specimens of objects in natural history to the University of Wisconsin, and to the other schools and colleges of the state.

SECTION 5. It shall be the duty of said Academy to keep a careful record of all its financial and other transactions, and at the close of each fiscal year, the president thereof shall report the same to the governor of the state, to be by him laid before the legislature.

SECTION 6. The constitution and by-laws of said Academy now in force shall govern the corporation hereby created, until regularly altered or repealed; and the present officers of said Academy shall be officers of the corporation hereby created, until their respective terms of office shall regularly expire, or until their places shall be otherwise vacated.

SECTION 7. Any existing society or institution having like objects embraced by said Academy, may be constituted a department thereof, or be otherwise connected therewith, on terms mutually satisfactory to the governing bodies of the said Academy and such other society or institution.

SECTION 8. For the proper preservation of such scientific specimens, books and other collections as said Academy may make, the governor shall prepare such apartment or apartments in the capital as may be so occupied without inconvenience to the state.

SECTION 9. This act shall take effect and be in force from and after its passage.

Approved March 16, 1870.

CONSTITUTION.

NAME AND LOCATION.

SECTION 1. This association shall be called "The Wisconsin Academy of Sciences, Arts and Letters," and shall be located at the city of Madison.

GENERAL OBJECTS.

SECTION 2. The general object of the Academy shall be to encourage investigations and disseminate correct views in the various departments of Science, Literature and the Arts.

DEPARTMENTS.

SECTION 3. The Academy shall comprise separate Departments, not less than three in number, of which those first organized shall be:

1st. *The Department of Speculative Philosophy*—

Embracing:

- Metaphysics;
- Ethics.

2d. *The Department of the Social and Political Sciences*—

Embracing:

- Jurisprudence;
- Political Science;
- Education;
- Public Health;
- Social Economy.

3d. *The Department of the Natural Sciences*—

Embracing:

- The Mathematical and Physical Sciences;
- Natural History;
- The Anthropological and Ethnological Sciences.

4th. *The Department of the Arts*—

Embracing:

- The Practical Arts;
- The Fine Arts.

5th. The Department of Letters—

Embracing:

Language;
Literature;
Criticism;
History.

SECTION 4. Any branch of these Departments may be constituted a section; and any section or group of sections may be expanded into a full department, whenever such expansion shall be deemed important.

SECTION 5. Any existing society or institution may be constituted a Department, on terms approved by two-thirds of the voting members present at two successive regular meetings of the Academy.

SPECIAL OBJECTS OF THE DEPARTMENTS.

SECTION 6. The specific objects of the Department of Science shall be:

1. General Scientific Research.
2. A progressive and thorough Scientific Survey of the State, under the direction of the Officers of the Academy.
3. The formation of a Scientific Museum.
4. The Diffusion of Knowledge by the publication of Original Contributions to Science.

The objects of the Department of Arts shall be:

1. The Advancement of the Useful Arts, through the Applications of Science and the Encouragement of Original Invention.
2. The Encouragement of the Fine Arts and the Improvement of the Public Taste, by means of Honors and Prizes awarded to Works of Superior merit, by Original Contributions to Art, and the formation of an Art Museum.

The object of the Department of Letters, shall be:

1. The Encouragement of Philological and Historical Research.
2. The Improvement of the English Language.
3. The Collection and Preservation of Historic Records.
4. The Formation of a General Library.

MEMBERSHIP.

SECTION 7. The Academy shall embrace four classes of governing members who shall be admitted by vote of the Academy, in the manner to be prescribed in the By-Laws:

1st. Annual Members, who shall pay an initiation fee of five dollars, and thereafter an annual fee of two dollars.

2d. Members for Life, who shall pay a fee of one hundred dollars.

3d. Patrons, whose contributions shall not be less than five hundred dollars.

4th. Founders, whose contributions shall not be less than the sum of one thousand dollars.

Provision may also be made for the election of Honorary and Corresponding Members, as may be directed in the By-Laws of the Academy.

MANAGEMENT.

SECTION 8. The management of the Academy shall be entrusted to a General Council; the immediate control of each Department to a Department Council. The General Council shall consist of the officers of the Academy, the officers of the Departments, the Governor and Lieutenant Governor, the Superintendent of Public Instruction, and the President of the State University, the President and Secretary of the State Agricultural Society, the President and Secretary of the State Historical Society, Counselors *ex officios*, and three Counselors to be elected for each Department. The Department Councils shall consist of the President and Secretary of the Academy, the officers of the Department, and three Counselors to be chosen by the Department.

OFFICERS.

SECTION 9. The officers of the Academy shall be: a President, who shall be *ex-officio* President of each of the Departments; one Vice-President for each Department; a General Secretary; a General Treasurer; a Director of the Museum, and a General Librarian.

SECTION 10. The officers of each Department shall be a Vice-President, who shall be *ex-officio* a Vice-president of the Academy; a Secretary and such other officers as may be created by the General Council.

SECTION 11. The officers of the Academy and the Departments shall hold their respective offices for the term of three years and until their successors are elected.

SECTION 12. The first election of officers under this Constitution shall be by its members at the first meeting of the Academy.

SECTION 13. The duties of the officers and the mode of their election, after the first election, as likewise the frequency, place and date of all meetings, shall be prescribed by the By-Laws of the Academy, which shall be framed and adopted by the General Council.

SECTION 14. No compensation shall be paid to any person whatever, and no expenses incurred for any person or object whatever, except under the authority of the Council.

RELATING TO AMENDMENTS.

Section 15. Every proposition to alter or amend this constitution shall be submitted in writing at a regular meeting; and if two-thirds of the members present at the next regular meeting vote in the affirmative, it shall be adopted.

AMENDMENTS TO THE CONSTITUTION.

Amendment to Section 3: "The Department of the Arts shall be hereafter divided into the Department of the Mechanic Arts and the Department of the Fine Arts." Passed February 14, 1876.

BY-LAWS.

ELECTION OF MEMBERS.

1. Candidates for membership must be proposed in writing, by a member, to the General Council and referred to a Committee on Nominations, which Committee may nominate to the Academy. A majority vote shall elect. Honorary and corresponding members must be persons who have rendered some marked service to Science, the Arts, or Letters, or to the Academy.

ELECTION OF OFFICERS.

2. All officers of the Academy shall be elected by ballot.

MEETINGS.

2. The regular meetings of the Academy shall be held as follows:

On the 2d Tuesday in February, at the seat of the Academy; and in July, at such place and exact date as shall be fixed by the Council; the first named to be the Annual Meeting. The hour shall be designated by the Secretary in the notice of the meeting. At any regular meeting, ten members shall constitute a quorum for the transaction of business. Special meetings may be called by the President at his discretion, or by request of any five members of the General Council.

DUTIES OF OFFICERS.

☐ 4. The President, Vice-President, Secretaries, Treasurer, Director of the Museum and Librarian shall perform the duties usually appertaining to their respective offices, or such as shall be required by the Council. The Treasurer shall give such security as shall be satisfactory to the Council, and pay such rate of interest on funds held by him as the Council shall determine. Five members of the General Council shall constitute a quorum.

COMMITTEES.

5. There shall be the following Standing Committees, to consist of three members each, when no other number is specified:

On Nominations.
On Papers presented to the Academy.
On Finance.
On the Museum.

On the Library.

On the Scientific Survey of the State; which Committee shall consist of the Governor, the President of the State University, and the President of this Academy.

On Publication; which Committee shall consist of the President of the Academy, the Vice-Presidents, and the General Secretary.

MUSEUM AND LIBRARY.

6. No books shall be taken from the Library, or works or specimens from the Museum, except by authority of the General Council; but it shall be the duty of said Council to provide for the distribution to the State University and to the Colleges and Public Schools of the State, of such duplicates of typical specimens in Natural History as the Academy may be able to supply without detriment to its collections.

ORDER OF BUSINESS.

7. The order of business at all regular meetings of the Academy or of any Department, shall be as follows:

Reading of minutes of previous meeting.
Reception of donations.
Reports of officers and committees.
Deferred business.
New business.
Reading and discussion of papers.

SUSPENSION AND AMENDMENT OF BY-LAWS.

8. The By-Laws may be suspended by a unanimous vote, and in case of the order of business a majority may suspend. They may be amended in the same manner as is provided for in the Constitution, for its amendment.

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The academy has a limited number of copies of volumes II–VIII of its Transactions, which may be purchased at two dollars per volume. Address Wm. H. Hobbs, Secretary, Madison, Wisconsin.

The Library Committee of the Academy is endeavoring to enlarge the library and render it more serviceable to members. It has been thought best to ask scientific workers to present the library with separates of their personal papers. The gifts will be acknowledged and the titles of papers will be printed after the author's name in the annual report of the librarian. It is requested that packages from abroad be forwarded through the agencies of the Smithsonian Institution.

It is further suggested to American workers that the library does not possess the reports of the State Geological Surveys, with the exception of Pennsylvania, Arkansas, Minnesota, Wisconsin, and some of the volumes of Maine, Illinois and Ohio. The method of distribution of these valuable documents adopted by many states, makes it difficult to obtain them except through the courtesy of individuals.

Direct packages to or address the Librarian of the Wisconsin Academy of Sciences, Arts and Letters, Madison, Wisconsin.