Committee on Publication

PROCEEDINGS

OF THE

Washington Academy of Sciences

VOL. VII

1905

WASHINGTON
JUNE, 1905 - MARCH, 1906

AFFILIATED SOCIETIES.

Anthropological Society of Washington.
Biological Society of Washington.
Botanical Society of Washington.
Chemical Society of Washington.
Columbia Historical Society.
Entomological Society of Washington.
Geological Society of Washington.
Medical Society of the District of Columbia.
National Geographic Society.
Philosophical Society of Washington.
Society of American Foresters.
Washington Society of the Archæological Institute of America.

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Lancaster, Pa.

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WASHINGTON ACADEMY OF SCIENCES

OFFICERS ELECTED JANUARY 18, 1906

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Charles D. Walcott

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Archæological Society	John W. Foster
Biological Society	F. H. Knowlton
Botanical Society	J. N. Rose
Chemical Society	F. W. Clarke
Columbia Historical Society	A. R. Spofford
Entomological Society	Wm. H. Ashmead
Geological Society	C. W. Hayes
Medical Society	James D. Morgan
National Geographic Society	Willis L. Moore
Philosophical Society	Cleveland Abbe
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Committee on Meetings

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Committee on Affiliation

O. H. Tittmann, *Chairman*
F. W. Clarke
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EIGHTH ANNUAL REPORT OF THE SECRETARY, 1905.

TO THE WASHINGTON ACADEMY OF SCIENCES.

Mr. President and Members of the Academy: I have the honor to present a brief statement of the operations of the Academy during the period from January 19, 1905, to January 18, 1906.

During this time the Academy has held the following meetings:

January 19, 1905 — Annual meeting for the election of officers, etc.

February 16, 1905 — Meeting to hear a discourse by Mr. Edward S. Curtis, who gave an account of his work in photographing western Indians, illustrated by lantern views.

March 9, 1905—Meeting for the discussion of Modern Methods of Historical Research and Teaching. At this meeting the following papers were presented:

The work of the Carnegie Bureau of Historical Research, by Prof. A. C. McLaughlin, Director.

Methods of Historical Research, by Prof. Charles M. Andrews, of Bryn Mawr College.

The Necessity in America of the Study of the Early History of Modern European Nations, by Prof. F. Keutgen, University of Jena, *pro tem.* Johns Hopkins University.

March 30, 1905 — Meeting to hear a paper by Prof. Frank Dawson Adams, of McGill University, relating to his experiments designed to illustrate the Flow of Rocks.

April 19, 1905 — Meeting in conjunction with the National Academy of Sciences to inspect the Bureau of Standards.

May 9, 1905 — Meeting in conjunction with the Anthropological Society of Washington to hear the annual address of the President of that Society, whose subject was "The Story of the Anthropological Society of Washington."

November 28, 1905 — Meeting to hear an address by Prof. Wilhelm Ostwald, University of Leipzig, on The International Language.

December 18, 1905 — Meeting to hear an address by Prof. V. Bjerknes, of the University of Stockholm, on The Application of the Principles of Hydrodynamics and Thermodynamics to Weather Predictions. This was discussed by Prof. E. W. Brown, of Haverford College, Messrs. R. S. Woodward and Cleveland Abbe.

The Board of Managers of the Academy has meanwhile held nine meetings for the transaction of business.

The Academy has suffered the following losses by death during the year:

Washington Matthews died April 29, 1905.
George H. Eldridge died June 29, 1905.
R. B. Warder died July 23, 1905.
W. R. Harper died January 10, 1906.
Swan M. Burnett died January 18, 1906.

The statistics of membership at this date are as follows:

Patrons.			
At date of last report	8		
Elected during the year	0		8
Resident members.			
At date of last report	157		
Elected and qualified during the year	21		
Transferred from non-resident list	1	179	
Deceased	4		
Resigned	7		
Dropped for non-payment of dues	1	12	167
Non-resident members.			
At date of last report	159		
Elected and qualified during the year	22	181	
Deceased	1		
Resigned	6		
Transferred to resident list	1	8	173
			348
Counted twice			1
Total membership January 18, 1906			347

Respectfully submitted,

FRANK BAKER,
Secretary.

JANUARY 18, 1906.

EIGHTH ANNUAL REPORT OF THE TREASURER, 1905.

TO THE WASHINGTON ACADEMY OF SCIENCES:

The Treasurer has the honor to submit the following annual report of receipts, disbursements, and funds in his hands for the year from January 16, 1905, to December 31, 1905, when the account was closed and balanced.

The receipts during the year were as follows :

Dues of resident members,	1899	$ 10.00	
Dues of resident members,	1900	10.00	
Dues of resident members,	1901	10.00	
Dues of resident members,	1902	10.00	
Dues of resident members,	1903	15.00	
Dues of resident members,	1904	90.00	
Dues of resident members,	1905	745.00	$ 890.00
Dues of non-resident members,	1901	10.00	
Dues of non-resident members,	1902	15.00	
Dues of non-resident members,	1903	15.00	
Dues of non-resident members,	1904	45.10	
Dues of non-resident members,	1905	810.10	
Dues of non-resident members,	1906	10.00	905.20
Sales of publications			81.60
Interest on bank deposit and investments			516.04
Refund from overpayment on disbursing voucher			.30
From Estate of Dr. S. C. Busey :			
3 year $4\frac{1}{2}\%$ first trust note		$444.44	
Cash		225.09	669.53
Cash returned by Committee on Meetings, balance not used expenses meeting of Dec. 18, 1905			3.05
Total receipts			$3,065.72

The amounts and objects of the expenditures were as follows :

Paid on account of expenses incurred in previous year, 1904 :		
Secretary's office	$ 19.70	
Treasurer's office	12.25	
Editor's office	500.00	
Publishing Vol. VI. of PROCEEDINGS	938.42	
Meetings	10.00	$1,480.37
Paid on account of expenses of the past year, 1905 :		
Secretary's office	$ 172.10	
Treasurer's office	105.30	
Meetings and Lectures	370.28	
Joint Directory	319.31	
Publishing Vol. VII of the PROCEEDINGS	1,192.75	
Investment in two 5%, 3-year deed of trust notes	3,500.00	
Investment to balance receipt of note from Estate of Dr. S. C. Busey	444.44	6,104.18
Total disbursements		$7,584.55

STATEMENT OF ACCOUNT.

Balance from last annual statement	$5,329.36
Receipts during the year	3,065.72
To be accounted for	$8,395.08
Disbursements during the year	7,584.55
Cash balance on hand	$ 810.53

These funds are on deposit with the American Security and Trust Company, drawing 2% interest.

The investment of $3,500.00 was made in two 3-year 5% first mortgage notes by Laura R. Green, on January 30, 1905. During the year there were received from the Estate of Dr. S. C. Busey a 3-year 4½% first trust note for $444.44, and $225.09 in cash, being the remainder of the bequest to the Academy.

The investments are as follows:

Cash on hand belonging to permanent fund	$ 195.09
809 shares stock of the Washington Sanitary Improvement Co	8,090.00
1 share stock of Colonial Fire Insurance Co	100.00
2 shares stock of the Scheutzen Park Land and Building Association, par value $100, actual value doubtful, say $44.00	88.00
2 first trust notes of Laura R. Green, 3 years 5% interest, for $2,000 and $1,500	3,500.00
1 first trust note of Aurelius R. Shands, 3 years, 4½% interest	444.44
	$12,417.53

Respectfully submitted,

BERNARD R. GREEN,
Treasurer.

JANUARY 18, 1906.

PROCEEDINGS

OF THE

WASHINGTON ACADEMY OF SCIENCES

VOL. VII, PP. 1-25. JUNE 20, 1905.

THE RELATIONS OF SOME CARBONIFEROUS FAUNAS.[1]

BY GEORGE H. GIRTY.

HOWEVER wide the deviation in practice, a description of the admirable scientific method as being that in which evidence or authority is adduced for each new or undemonstrated statement, would probably meet with general acceptance; yet departure from this method is regarded as permissible in certain cases, and scientific discussion does find a legitimate field in which the presentation of evidence plays a subordinate part. It is believed that the subject of the present paper presents such a field, yet my own indisposition toward publications of this sort is such that the manuscript has been withheld for many months, largely through unwillingness to enter it. The fact that the following pages are a presentation of problems for solution rather than a statement of results, with its implicated claim to priority, will, it is hoped, serve my excuse. A man with an arrow may hit a mark which another laboriously has his hand upon, and it seems as if far too much of that prized commodity, credit, were commonly awarded to priority of statement as against priority of demonstration.

During the past 9 or 10 years collections of Carboniferous invertebrate fossils have come under my observation in great numbers, and from a very extensive area. Many facts relating to the dispersion and relation of faunas have thus been ascertained, or divined with greater or less certainty; but the very

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[1] Published by permission of the Directors of the U. S. Geological Survey.

amount and variety of the evidence which passed before me, together with the pressure of other work, has prevented the making of final comparisons and the developing of evidence in such detail that conclusions could be said to be proved to myself, or that they could be presented for the conviction of others.

Until this could be carried out I thought to refrain from publishing these observations; but it has latterly seemed to me that many of them are of sufficient interest and sufficiently well substantiated to make a statement desirable, even though my views should subsequently need to be modified and though the presentation of the evidence upon which they are based should prove to be, as it clearly will, the work of years. It is partly on this account, the necessity of choice between the early statement of conclusions which are more or less tentative, and a delayed and gradual presentation of better established ones, together with the feeling that to formulate these views now might aid myself as well as others in a more speedy arrival at the truth, by determining what the objective really is, that the former course has been chosen.

Several years ago I studied and described in detail the fauna of the Madison limestone of Yellowstone National Park.[1] This fauna proves to be characteristic of the Lower Carboniferous of the Western States, in nearly every one of which it occurs, locally modified perhaps, but retaining the same general expression, from the Canadian to the Mexican boundary and as far west as Nevada. In California the fauna of the Baird shale, which has generally been called Lower Carboniferous, is entirely different, and while it has not yet been found in Washington or Oregon, it seems probable that the areas of those States shared the same geological and biological history during this period. The Mississippian faunas of the Mississippi valley seem never to have found entrance into this region, or, if so, whatever traces have not been lost are thus far undiscovered. On the other hand, it is uncertain if the California fauna ever penetrated into the region eastward. One of its most striking features is a large *Productus* resembling *P. giganteus* of the

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[1] U. S. Geol. Surv., Mon. No. 32, 1899, pt. 2, chap. 12, sec. 2.

English "Mountain limestone." This species is not known elsewhere in North America, unless a form identified by Meek as *Productus latissimus* prove to be the same. The latter was found on Katlahwoke Creek, Montana, and is the only indication of the Baird fauna known to me east of the Pacific coast.[1] If it does mark this fauna, the latter will appear to have had a wider distribution eastward than there is otherwise ground for supposing. There is thus no very conclusive evidence for believing that the Bairdian fauna was contemporaneous with those of the Mississippi Valley, rather than of later development, but even if so the facies of the two are so different that the propriety of extending to the California fauna the term Mississippian may well be questioned.

The fauna of the Madison limestone, which has so wide a distribution in the West, is, on the other hand, closely related to the typical Mississippian faunas. In my earlier work I correlated the Madison limestone with the Kinderhook, Burlington, and Keokuk groups of the Mississippi Valley, and have seen no reason since to change my views. Nevertheless, it seems to be almost unquestionable that in some areas these Western faunas, in their later developments, take on the aspect characteristic of the St. Louis epoch. Nowhere in the West, however, have any Kaskaskia faunas been discovered. One of 3 hypotheses seems necessary to explain this fact, which is no less striking, even should local areas of Kaskaskia rocks subsequently be discovered. Either no strata equivalent to the Kaskaskia have ever been deposited in this region; or, though deposited, they have since been removed; or else contemporaneously formed sediments supported a fauna which was so unlike the Kaskaskia that its equivalence has failed of recognition. Of these 3 hypotheses it is probable that the second is the correct one. Unmistakable evidence of unconformity beween the Madison limestone (and its correlates) and the over-

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Bernard R. Green,
Treasurer.

January 18, 1906.

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lying beds has been found in so many points in the West that a period of erosion previous to the earliest Pennsylvanian sediments can be hypothetized for all this Western country, a generalization which is all the more safe from the widespread evidence of a similar occurrence in the central and eastern United States, and indeed in other parts of the world.

In some areas the Upper Carboniferous follows the Lower without apparent unconformity and without marked lithologic change, but still with a faunal break and the elision of Kaskaskia faunas. This is true of southern Arizona and perhaps of the entire State, where the rocks of both epochs are limestones formed, to all appearances, in an unbroken sequence; yet a faunal gap occurs, and even in this case, at least with the present evidence, we must probably proceed on the hypothesis that discontinuity, if not visible erosion, divided the 2 series of sediments.

The fauna of the Madison limestone, and that of the various formations which must be correlated with it in different parts of the West, has been said to be equivalent to those of the Kinderhook and Osage groups. This affinity is, however, especially with the Chouteau, and with the Cuyahoga fauna of the Waverly group, which can probably be correlated with it. This fact is justly remarked by Mr. Weller,[1] and was not unrecognized by me, although it seems, I failed to call attention to it. The Madison faunas lack many of the striking features of those of the Burlington and Keokuk, both the wealth of crinoids and such robust types as *Spirifer grimesi*, *S. logani*, *Schizophoria swallowi*, *Athyris incrassata*, etc. In fact, while the Lower Carboniferous rocks of the Mississippi Valley form a standard section for the United States, it seems probable that they are really the expression of somewhat abnormal conditions. The aggregation of crinoid life, which is perhaps unequaled the world over, if not the result of unusual conditions would at least create them for the associated fauna, and to this fact may perhaps be largely attributed the characteristic facies of the Burlington and Keokuk groups. That these conditions were widely spread seems to be certain, and they extended to or oc-

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[1] Acad. Sci. St. Louis, Trans., vol. 11, No. 9, 1901, p. 210.

curred independently in New Mexico, where, as is well-known, crinoid beds usually assigned to the Burlington, with an associated fauna reminiscent of the Osage, are found. But this condition appears not to have invaded other western portions of the Mississippian sea, where I believe, under uniform conditions, the Kinderhook faunas persisted through Burlington and Keokuk time without feeling, save in a subordinate degree, the influences which helped to differentiate the early Mississippian faunas of the Mississippi Valley. The Mississippian beds of the West are almost invariably purely calcareous, showing a uniformity of condition, which finds its reflex and expression in the nearly uniform fauna that persisted, with slight and very gradual variation, from bottom to top of the series.

In Ohio again, conditions were nearly uniform, and were at least apparently unaffected by the profuse crinoid life, which, whether as a partial expression or as a cause, helped to modify Kinderhook life into its Burlington and Keokuk phases. Here sedimentation comprised clay and mud, without any beds of lime whatsoever. The Waverly rocks of Ohio are more varied, however, than the Madison limestone, being divided, as is well known, into several formations, and the faunas too are apparently more differentiated. Here also striking Burlington and Keokuk features are not found, but the time of these 2 epochs is probably represented by the upper part of the Waverly group.

In spite of what Hall, Herrick, and others have written, I am quite satisfied of the Carboniferous age of the Waverly group as a whole. This statement requires, however, some qualification. The Waverly section as given by Prosser[1] consists of the following formations, from below upward: Bedford shale, Berea grit, Sunbury shale, Cuyahoga formation, Blackhand formation, and Logan group. The Cuyahoga shale itself is capable of subdivision, as will shortly appear. Of all these strata the only faunas at all well known are those of the Logan, Blackhand, and upper Cuyahoga formations. The lower Cuyahoga is scantily fossiliferous; the Sunbury shale contains little besides *Lingula* and *Orbiculoidea;* the Berea grit is almost

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[1] Jour. Geol., vol. 9, No. 3, 1901, p. 215.

without fossils, except fishes, and the upper portion of the Bedford is practically unfossiliferous. The lowest Bedford, however, often contains an abundant though somewhat limited fauna, part of which has been illustrated by Herrick.[1] It is the middle and upper Cuyahoga faunas and those of the Blackhand and Logan formations which should be correlated with the Kinderhook, Burlington, and Keokuk groups of the Mississipi Valley. It is probable, however, that the Mississippian is initiated with the Berea grit, because the Bedford fauna comprises a well-defined group of species, quite distinct from any of the Waverly or Mississippian faunas. The lower Cuyahoga fauna, so far as it is known, is allied to that of the middle and upper portion. The supposed equivalent of the Berea grit in northwesten Pennsylvania contains a fauna which is without much question of a Mississippian type, and furthermore, both theoretically, and practically for mapping purposes, the Berea grit is a satisfactory bed with which to initiate the Carboniferous series.

From Ohio the Waverly group passes eastward into northwestern Pennsylvania. There, in his reports on Crawford and Erie counties, I. C. White[2] has called the several members by different names. The Blackhand conglomerate is his Shenango sandstone, and apparently the Logan group is represented by his Shenango shale. His Meadville shale, Sharpsville sandstone, and Orangeville shale are, respectively, the upper, middle, and lower portions of the Cuyahoga shale. In this region the Sunbury shale is either absent or merged with the lower Cuyahoga. The Berea grit of Ohio is White's Cussewago sandstone, together with probably the Cussewago flags and Corry sandstone.[3]

From Crawford and Erie counties the Corry sandstone can be traced eastward to Warren, where it lies approximately 500 feet

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[1] Sci. Lab. Denison Univ., Bull., vol. 4, 1888, pl. 9.

[2] Second Geol. Surv. Penn., Rept., Q4, 1881.

[3] Many of these correlations have been pointed out by Stevenson (Geol. Soc. Am., Bull., vol. 14, pp. 27 and 42) and also by White in his report on Crawford and Erie counties, above referred to. The views expressed above are based upon my own field work, by which the formations and faunas were traced from Pennsylvania over extensive areas in Ohio.

above the top of the true Chemung. The intervening beds seem, therefore, to represent a new time interval between the Devonian and the Carboniferous, for which the name Bradfordian has been suggested.

The extent of the Bradfordian series, which includes beds sometimes loosely termed "Upper Chemung," is not definitely known, but the evidence thus far obtained indicates that the Pocono and possibly part of the Catskill belong to it. If this is true, and if the correlations summarized by Stevenson in the report just cited, are in the main correct, this series plays an important part in the geology of the Appalachian basin. Therefore, in my view, which I hope shortly to support by a complete presentation of evidence, the Pocono, if it actually forms part of the Bradfordian series, instead of being equivalent to the Waverly, as generally supposed, passes under it in the vicinity of Warren, the real Waverly apparently not extending farther to the eastward. The Bradfordian series is frequently exposed in Crawford and Erie counties, where it includes the Riceville shale and, doubtless, considerable thicknesses of the underlying beds. In Ohio it is tentatively assumed to be represented by the Bedford and Cleveland shales, and probably by the Erie. Its age is a matter of some diversity of opinion, but I believe that its true relations are with the Devonian.

In the Central States the Mississippian series is usually succeeded by a bed of sandstone or conglomerate, followed by the Coal Measures, and in many cases preceded by an erosional unconformity. This basal sandstone, often called the "Millstone grit" or "Coal Measure conglomerate," has always been classed with the Upper Carboniferous, and has been regarded as ushering in the Upper Carboniferous or Pennsylvanian. Comparatively seldom does it contain fossils of any kind, and never, so far as I am aware, invertebrate fossils. On this account, and because it is not in this area of very great thickness, it has generally been given little consideration by invertebrate paleontologists, the arena of whose investigations has been largely confined to these North Central States. Nevertheless, this horizon is probably destined to form a very interesting field for paleontologic research.

In Pennsylvania, between the Lower Carboniferous and the Coal Measures, intervenes, as is well known, the Pottsville series, a group especially noted for its sand and pebble beds, but often containing as well a large quota of shales, fire clays, and coals. The thickness attained by the Pottsville in the Appalachian region is in some cases upwards of 6,000 feet. The Pottsville series occupies a position in the section corresponding to the "Millstone grit" of the Central States, and the evidence of paleobotany, wherever obtained, shows that the "Millstone grit" represents the Pottsville, sometimes one portion, sometimes another, for the name has been applied not so much to the same bed as to similar beds occupying the same position. In the Appalachian region the Pottsville series is richly fossiliferous in the way of fossil plants, but furnishes as a rule few invertebrates. The invertebrate faunas are, except in a few instances, peculiar and restricted, and clearly indicate unusual environmental conditions. The most frequent fossil is *Naiadites elongatus* Dawson, with which are associated bivalve crustaceans, such as *Estheria*, *Leaia*, and Ostracods; while more rarely fragments of *Prestwichia*, or Limuloids, or fish scales and plates are brought to view. An occasional Pectinoid, almost always of the type of *Aviculipecten whitei*, together, not infrequently, with *Lingula* and *Orbiculoidea*, indicates that these faunas cannot be considered as owing their peculiar facies to strictly fresh-water conditions. Possibly the water was brackish, or else the impurity produced by decaying vegetation and acid products resulting therefrom exercised a prohibitive influence upon oceanic life. In a few cases strictly marine faunas have been found in the Appalachian Pottsville.

In Arkansas Branner[1] and the geologists associated with him worked out the following section, which has been somewhat modified by later investigations, both as to terminology and arrangement. Nevertheless, the form in which Branner presented it is better known and will suffice for the present discussion. The Carboniferous portion of the section contains the following formations, in ascending order: Boone chert and

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[1] Arkansas Geol. Surv., Ann. Rept. for 1888, vol. 4 (Washington County), 1891, p. 26.

and cherty limestone, Wyman sandstone, Fayetteville shale, Batesville sandstone, Marshall shale, Archimedes limestone, Washington shale and sandstone, Pentremital limestone, coal-bearing shale and Kessler limestone.

The coal-bearing shale contains a rich flora, which, though the fact has generally escaped recognition by invertebrate paleontologists, was identified several years ago by Mr. David White as of latest middle or earliest "Upper Pottsville" age. Nevertheless, the Boston group, that is, beds up to and including the Kessler limestone, has otherwise, without exception so far as I am aware, been assigned to the Lower Carboniferous. I have recently studied with some care the upper faunas of this section, and although my investigations are still incomplete, feel safe in making the following statement, of which my report, when published, will give the evidence in full.

The Kessler limestone is as a rule scantily fossiliferous, but where a fauna has been obtained from it, it proves to be essentially the same as that of the Petremital limestone. Thus these 2 limestones, carrying between them the coal-bearing shale with its "Upper Pottsville" flora, are inseparable upon paleontologic evidence. The line, whatever division is used, must pass above the Kessler or below the Pentremital. The Kessler-Pentremital fauna is quite distinct from any standard Lower Carboniferous fauna; it is also markedly different from the fauna of the Archimedes limestone. There is thus a distinct faunal break between the Archimedes and Pentremital beds. The Pentremital-Kessler fauna is itself one of great interest. Besides many species which are new, it contains some showing Lower Carboniferous affinities, such as *Pentremites*, *Spiriferina transversa*, etc., and others which are distinctly Upper Carboniferous, *e. g.*, *Hustedia* and *Squamularia*. Few paleontologists will at first be willing to accept *Pentremites* as ranging above the top of the sub-Carboniferous, but the evidence at hand leaves no other conclusion tenable, unless one be prepared to place the Pottsville beds in the Lower Carboniferous.

From what has already been said, the Pottsville, from its faunal side, is of little interest in the way of correlation in the Central and Eastern States. It will, however, probably establish some interesting relations between beds of the West and the Southwest. The Pennsylvanian faunas of the West have often a facies which is novel and perplexing to one familiar only with the well-known Eastern ones; and it is probable that the lowest faunas of this region will in many cases prove to be of Pottsville age. While I have not been able as yet to make the numerous identifications and comparisons necessary to establish this as a fact, the resemblances to the fauna of the Morrow formation (Pentremital limestone, coal-bearing shale, and Kessler limestone) are sufficiently numerous and striking to make this a very promising hypothesis.

It will be remembered that C. D. Walcott described an interesting fauna from the Eureka district,[1] in which there was found a commingling of Upper and Lower Carboniferous types. This is likely to prove of Pottsville age. The lowest Pennsylvanian faunas of Colorado and of New Mexico, especially the latter, also show similarities which appear to me highly significant. The Bend and Millsap formations of Texas may likewise prove to be Pottsville. In Indian Territory the Wapanucka limestone, whose fauna I at one time described[2] in a very limited and cursory manner, is, I feel fairly well assured, to be closely correlated with the Pentremital and Kessler beds.

The faunas of the middle and lower Pottsville are as yet unknown, unless to this horizon belong the beds underlying the Morrow formation in Arkansas and the Wapanucka limestone in Indian Territory. The possibility involved is interesting, and deserves investigation. The case may be stated as follows: The faunas between the Boone and the Pentremital have always been regarded as belonging in the upper Mississippian (Genevieve), in which case the lower and middle Pottsville are unrepresented in this area. Now the stratigraphic and lithologic break at the top of the Boone is as strong as, possibly stronger than, that at the base of the Morrow formation. Furthermore, while the faunas of the beds between the Boone and Kessler show marked Mississippian affinities, they at the same time possess much individuality. The resemblances to the Gene-

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[1] U. S. Geol. Surv., Mon. 8, 1884.

[2] U. S. Geol. Surv., 19th Ann. Rept., pt. 3, 1899, pp. 543, 573.

vieve are probably no greater than one would expect in the case of an immediately succeeding series, while the differences are rather more than one would expect in the same series at a point relatively so near the typical Genevieve area. The supposed dispersion also of the beds under consideration seems to afford some support for the view advanced.

Beneath the Wapanucka limestone in Indian Territory lies the Caney shale, a great mass of black shale, sometimes reaching a thickness of 1,500 feet, which probably is, in a general way, or partially, equivalent to the interval under consideration — that between the Boone and the Kessler formations. This interval, it will be remembered, also contains a good deal of black shale, and underlies the Kessler limestone, which I correlate with some confidence with the Wapanucka limestone, though, as already remarked the final specific comparisons and identifications have not yet been made. The Caney shale, however, is, in its fullest development, much thicker than the beds in Arkansas, and an opinion would at present be hazardous, as to whether only a part of it represents them, or the entire thickness is merely an expansion.

The fauna of the Caney shale consists largely of Goniatites, which are both varied and abundant in certain localities, where they help to form calcareous lentils. With the Goniatites occur little besides, except at some points a small species of *Posidoniella* in great abundance. At the base of the Caney at one locality a more varied though somewhat sparse and ill-preserved fauna has been found. This fauna and the Goniatites, some of which are of the *crenistria* and *sphæricus* types, are very suggestive of the fauna of the Fayetteville shale and Spring Creek limestone. The Caney rests sometimes upon lower Helderberg rocks, sometimes upon those of Ordovician age; and Mr. Taff tells me that his field work of the present season tends to demonstrate the presence over a considerable area of a great thickness of sandstones and shales of Carboniferous and probably Pennsylvanian age, beneath it.

In the White Pine district of Nevada the beds called "Lower Carboniferous" by Mr. Walcott, which are here suggested to be of Pottsville age, are underlain by a black shale — the White

Pine shale — which he assigned to the "Upper Devonian." I have long been of opinion, however, that the age of this bed is not Devonian, but Carboniferous. The White Pine fauna, however, is not without forms suggestive of the Devonian, to which period it was also tentatively assigned by Meek. One of the most striking of these is a *Leiorhynchus* resembling *L. quadricostatum*. *Productus hirsutiformis* and a *Posidonomya* (*Posidoniella ?*) also lend it a Devonian aspect. A *Leiorhynchus* like *L. quadricostatum*, a *Productus* like *P. hirsutiformis*, similar Goniatites, and similar *Posidoniellas* are found near the base of the Caney shale in Indian Territory, and in the Spring Creek limestone and Fayetteville shale of Arkansas. These facts, together with a similarity in lithologic character and an identity in stratigraphic position, in point of which each occurrence is immediately beneath beds supposed to represent about the same horizon, while not sufficient to demonstrate stratigraphic equivalence, for which a thorough comparison of the entire faunas would be necessary, lend a strong color of probability to it. The occurrence of the White Pine shale corresponds to the Caney shale in that no beds of Mississippian age underlie it. In Nevada, however, we have a great thickness of Devonian, perhaps the most notable instance of Devonian west of the Mississippi Valley, an equivalent of which is lacking in Indian Territory.

Assuming the correctness of the correlation thus tentatively adopted, the uniformity of distribution of the black-shale horizon with the overlying sandstone and limestone is suggestive of a close relation between them. On the other hand, at the base of this horizon a great discordance appears to exist, measured to some extent by the various ages of the beds upon which it rests, now Mississippian, now Ordovician, and again upon Devonian strata. On the hypothesis that this black-shale interval represents the early portion of the Pottsville series, this apparent unconformity at its base would probably coincide with the period of erosion, almost continental in extent, by which the Mississippian period was brought to a close. On the other hand, on the assumption that the black shale belongs in the upper Mississippian, it would appear that an extensive and little suspected discordance separates the Genevieve from the Osage groups, while the general unconformity preceding the Pottsville, which should intervene below the Morrow formation, is relatively insignificant. The survey of the situation thus hastily made, while inadequate to prove that the black-shale interval constitutes the early portion of the Pottsville series, does seem sufficiently to call in question the accepted disposition of these beds, to entitle their correlation to appear among the interesting Carboniferous problems of the United States.

There is also a chance that these beds may at the same time represent both upper Mississippian and "Lower Pottsville," for it can not as yet be demonstrated that part of the Pottsville is not a nonmarine equivalent to the marine Genevieve, or a portion of it; but from such facts as are known to me there seems little likelihood for this to be the case.

If the interval under consideration does not represent the earlier portion of the Pottsville series, but corresponds to the later epochs of the Mississippian series, it is evident that terraqueous conditions, expressed in sediments and faunas, were very different in the northern and southern parts of the inland sea. This period would then present a case somewhat analogous to that of the middle portion of the Devonian, which is represented by varied sediments and faunas in New York, but to the south and west, according to some views, is replaced by a single uniform bed of nearly barren black shale. The peculiar development of the Arkansas faunas from the Boone to the Morrow might be explained as modifications imposed upon the typical Genevieve fauna by the proximity to and occasional invasions of black-shale conditions. Upon this hypothesis, also, an exception to the statement that Genevieve faunas are almost entirely lacking in the west, would be furnished in the case of the White Pine shale of Nevada, which is here provisionally and in a general way aligned with the interval above the Boone in Arkansas.

It is a matter of common knowledge that the Upper Carboniferous faunas of the Western States differ to some extent from those of the Mississippi Valley and the Appalachian region. Part of this diversity, as already remarked, seems to be due to the fact that the horizon of some of the beds corresponds to one in the East whose fauna is for the most part scanty and is as yet practically unknown (Pottsville). On the other hand, a number of the Western faunas are quite distinct and altogether unknown in the East. Reciprocally, the familiar upper Pennsylvanian faunas of Kansas and Nebraska have not been found in a facies at all characteristic in the Western region.

Within the past 2 or 3 years I have given much preliminary study to the faunas of the Trans-Pecos region of Texas and New Mexico, where is found the longest section of Pennsylvanian rocks in the West of which I have personal knowledge, aggregating in all over 6,000 feet. The upper portion of this section constitutes what I have called the Guadalupian series. The upper division of the Guadalupian consists of the Capitan limestone, some 1,800 feet thick, and the lower is the Delaware Mountain sandstone, with a thickness somewhat greater. Beneath the Guadalupian series occurs the Hueco formation, or Hueconian, comprising upwards of 2,000 feet of limestone. The faunas of these formations are quite different from those of the Eastern States. Very few species can be definitely identified as common to both areas, and these are chiefly such as enjoy a world-wide distribution. Through the West, however, these faunas will probably prove to have extended widely. Their general character is shown in some preliminary lists in a report upon this region, by G. B. Richardson, recently issued as a bulletin of the Texas Geological Survey.[1] The Hueco formation, which is in the main a limestone, will perhaps prove to be the same as the Aubrey formation of northern Arizona, which consists of sandstone and limestone in alternation, and I am tentatively correlating these formations with the Weber quartzite of Utah. The Delaware division, comprising chiefly sandstones in the Guadalupe Mountains, with a few calcareous beds, but very variable in the character and proportions of its constituents, can possibly be correlated with the Permian of Walcott's Grand Canyon section and with the "Permo-Carboniferous" of the Wasatch Mountains. However, if there is some doubt about the correspondence of the Arizona beds, there is still more in

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[1] Univ. Texas Min. Surv., Bull. No. 9, Nov. 1904, pp. 32 et seq.

the case of those of Utah. In Utah an interesting fauna has been found between the Weber quartzite and the "Permo-Carboniferous," characterized by a striking *Spiriferina*, unique as to size among American representatives of the genus, namely *Spiriferina pulchra* Meek. This species is accompanied by a large *Orthotetes*, a large *Seminula*, a *Productus* resembling *P. nevadensis*, and other forms. This fauna ranges northward into Idaho and westward into Nevada, but is as yet unknown in the southern tier of States. The Capitan fauna is not definitely known anywhere except in the immediate region where it was originally found, and whatever the correlation of the beds of the Utah section may prove to be, there is little prospect of any of them being equivalent to the Capitan. At least their faunas, so far as known, are entirely different.

The Weber quartzite is underlain by a heavy limestone formation (the Wasatch limestone), the lower part of which is of Mississippian age, the upper being reported as Pennsylvanian. A similar limestone (the Redwall), likewise said to be Mississippian below and Pennsylvanian above, lies beneath the Aubrey group in northern Arizona. In southern Arizona a similar condition obtains. The lower limestone, which is probably as young as St. Louis in its upper portion but contains no Kaskaskia fauna, is called the Escabrosa limestone,[1] the upper one having received the name of the Naco limestone. The lower part of the Naco is provisionally correlated with the upper part of the Redwall limestone, and will probably prove of Pottsville age. The scanty fauna of the upper Naco appears to correlate it with the Hueco limestone and with the Aubrey formation. So far as known no equivalent of the Escabrosa and lower Naco limestones occurs in the Trans-Pecos region, where even the Devonian found at Bisbee is absent. Thus an unconformity is seen to have preceded the Hueconian beds, evidence of which is quite abundant in the Trans-Pecos region itself.

The Carboniferous faunas of California, typically shown in Shasta County, have appeared to stand apart from other Western faunas. The lower fauna, or that of the Baird shale, is in fact, so far as known, confined to the Pacific slope ; but a better

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[1] U. S. Geol. Surv., Professional Paper 21, 1904, p. 42, by F. L. Ransome.

acquaintance with Western faunas now seems to indicate that the associates of species found in the McCloud limestone and the "McCloud shale" are much more widely spread. The fauna of the McCloud limestone is characterized by the presence of *Schwagerina* in abundance and by the large gastropod *Omphalotrochus whitneyi*. The *Omphalotrochus* beds apparently recur in Nevada, and probably are to be correlated with the lower portion of the Hueco formation. At this horizon *Schwagerina* (?) is found in abundance, and a series of large Trochoid shells which may prove to belong to the genus *Omphalotrochus* but not without a certain modification of the generic diagnosis given by Meek. The "McCloud shale" may provisionally be correlated with the upper Hueconian. A striking faunal feature which these 2 horizons possess in common is a very large and slender *Fusulina*, probably *F. elongata* Shumard. It cannot be said positively that the same species are associated with these genera in every case, for the fossils have been examined at different times and in a preliminary way; but I believe that the faunas of the Trans-Pecos region, with aspect more or less modified, will be found to range through New Mexico, Arizona, Utah, Nevada, and California. Less abundant evidence is at hand with regard to Oregon, Washington, and Idaho, but doubtless the same seas and the same faunas occupied those areas as well as the western reaches of the British possessions, for the Alaskan faunas are certainly related to those of California, and also to those of the Trans-Pecos region.

No faunas have yet been obtained from Alaska which I feel confident can be referred to the Lower Carboniferous.[1] The typical Mississipian is certainly absent as far as evidence has come to hand, and but one occurrence of a fauna definitely related to the Lower Carboniferous of California (Baird) has been found. The Upper Carboniferous faunas present many novel and striking features, but their relationship to the Upper Carboniferous of California is clear and unmistakable. Naturally less close, though still distinctly traceable is a correspondence

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[1] There has recently come into my hands a good collection from the Cape Lisburne region which can safely be called Lower Carboniferous. Its affinities are more with the *Spirifer mosquensis* zone of Russia than with the typical Mississippian.

to the Trans-Pecos faunas. Neither in California nor in Alaska has the strongly characterized fauna of the Capitan limestone been discovered. The Alaskan faunas and, as already stated, those of the McCloud limestone and the "McCloud shale" can probably be correlated with the Hueconian fauna, with which, indeed, their affinities are chiefly shown. In Alaska, however, there are indications of faunas lower than the Hueconian, though not as yet of any higher.

The Upper Carboniferous faunas of the west were known to the earlier writers in an extremely sporadic and incomplete manner. In the last 20 years much more extensive and better correlated material has been obtained, which seems on the one hand to indicate a regularity of succession and an extent of distribution at first far from apparent, and on the other to emphasize an unlikeness to the faunas of the Mississippi Valley, which was always more or less obvious. The difference, which is manifested chiefly in the younger Carboniferous faunas, seems too great to be explicable under the hypothesis of merely local conditions acting upon identical faunas in freely communicating seas, and I am disposed to consider that the Western faunas may have had immediate antecedents different from the Eastern, and that they may have been prevented from intermingling with them, either by some terrestrial barrier or by such marked diversity of environment that neither assemblage of species could exist in the habitat of the other. The resemblance to eastern Pennsylvanian faunas seems to be manifested in the West, especially by those having a low position in the section, and they are often more or less closely allied with the Pottsville faunas of Arkansas. Therefore it is likely that areal differentiation took place after the beginning of Pennsylvanian time. Probably it was at the close of the Pottsville.

In a recent paper on the Carboniferous faunas of Colorado[1] 2 facts seemed to develop, namely, that the faunas of that State were of the usual Pennsylvanian type, and that the stratigraphy and lithology indicate disturbances and shore conditions during Pennsylvanian time. This is suggested by the general sandy and conglomeratic character of the Pennsylvanian

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[1] U. S. Geol. Surv., Professional Paper 16, 1903.
Proc. Wash. Acad. Sci., June, 1905.

sediments, and by the occurrence in them of pebbles containing Pennsylvanian fossils. On this account it is tentatively assumed that the line of division between the Eastern and Western provinces passes through western Texas, central or eastern New Mexico, western Colorado, and so on upward, in a northwestern direction, following nearly the trend of the Rocky Mountains. This matter, however, like that of the correlation and dispersion of the Pacific faunas, is left open to revision as new facts are added and as the mass of evidence now at hand is subjected to critical comparison and analysis.

The continental sea in Mississippian time, however, probably spread as far west as Nevada, and had almost the same limits during the Pottsville epoch, neither group of faunas, so far as known, having penetrated to the Pacific coast. But it would appear that during Pennsylvanian, and also probably during Permian time, its western term was fixed much farther east, its contracted limits favoring shallower depths and marginal conditions upon its eastern shore suitable for the formation of coal, and correspondingly unsuitable to marine life. To the west, beyond the hypothetical barrier, material or intangible, the unimpeded waters probably spread afar, and the faunas which they supported have much in common with those of Asia and eastern Europe.

The differences presented by these western faunas, when carefully compared with those of the Mississippi valley, are real and important, and the explanation suggested above is that during the later portions of Pennsylvanian time, they were developed in different provinces. If this explanation be rejected it apparently follows that the differences are due to geologic horizon rather than to geographic position. It seems almost impossible that the two series of faunas can be equivalent without belonging to different provinces, and very improbable that the eastern one overlies the western. On the hypothesis that they are coprovincial, therefore, to the column of Pennsylvanian rocks found in the Mississippi valley must be added a great series whose development was western and the facies of whose fauna is Asiatic. This series is not found east of the Rocky mountains unless it proves to be represented by the more or less unfossiliferous "Red Beds" which rest upon the meso-continental Pennsylvanian rocks, an eventuality for which I am not altogether unprepared since the limited fauna prescribed by Mr. Beede from the "Red Beds" of Oklahoma[1] has a distinctly younger and more Asiatic facies than any of the previously known Pennsylvanian faunal groups of the Mississippi valley. In that event the "Permian" of this region would be far older than the typical Russian Permian.

While the differences between our Western and Eastern faunas have been more or less apparent to all, they have seldom excited much comment, and, on the other hand, while comparison with the faunas of Europe and Asia has several times been made, striking parallels have not been the result. Doubtless incomplete and sometimes inexact acquaintance with the facts has partially obscured the relations of these faunas to the able investigators who have studied them, which large accessions to our data regarding both areas in recent years have rendered more and more conspicuous.

In the fall of 1900 I collected in the Guadalupe Mountains a fauna incompletely described 50 years ago by Shumard, which presents strong analogies with faunas called "Permian" described from the Salt Range of India, from the Carnic Alps, and from Sicily, and in a corresponding degree differs from those of central and eastern North America.

A recent work by Tschernyschew,[2] upon the Upper Carboniferous of the Urals and Timan, illuminates the consideration of the relations between the Carboniferous faunas of eastern Europe and western America, and shows that the lower as well as the higher faunas in the Trans-Pecos region are very analogous to those beyond the sea. Tschernyschew recognizes 5 zones in the strata described by him, which have the following succession, from below up: *Spirifer mosquensis* zone, *Spirifer marcoui* zone, *Omphalotrochus whitneyi* zone, *Productus cora* zone, and *Schwagerina* zone. *Omphalotrochus whitneyi* is one of the remarkable fossils of the McCloud limestone of the Cali-

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[1] Oklahoma Geol. Surv., Adv. Bull., 1st Bien. Rept., 1902.

[2] Die Obercarbonischen Brachiopoden des Ural und des Timan; Comité Géologique, Mem., vol. 16, No. 2, 1902.

fornia Carboniferous section, which has stood for a long time more or less solitary and unique among its kind in America, because of the singularity of its faunas. Accordingly, Tschernyschew correlates syntactically the *Omphalotrochus* zone of eastern Russia with the McCloud limestone of California. But the genus *Omphalotrochus* characterizes certain horizons over wide areas in Nevada, and by reason of a somewhat similar resemblance the Hueco formation of Western Texas may likewise be tentatively referred to the *Omphalotrochus* zone, for one horizon abounds in *Omphalotrochus*, several species of which occur.

The fossils of the Hueco, Delaware Mountain, and Capitan formations, as would be expected from their combined thickness, represent a sequence of related faunas, rather than a single uniform one. Whatever is here said about these faunas is qualified by the fact, on the one hand, that they are yet, as to detailed study, largely unworked, while, on the other, my acquaintance with the Uralian series is only such as literature affords. Nevertheless, I seem to see in the Texas faunas resemblances to the *Spirifer marcoui*, *Omphalotrochus whitneyi*, *Productus cora*, and *Schwagerina* zones as their fossils are represented by Tschernyschew. All three of the lower faunas are probably represented by the Hueco formation, while the fauna of the Capitan limestone is in some respects strikingly similar to that of the *Schwagerina* zone. Sundry types which seem to abound in the Russian beds, however, are thus far unknown in Texas, while in some cases the association of species is different, indicating that certain forms appeared later in one area than in the other, or had a different range. A fauna which I collected northeast of Hueco Tanks, on the brow of the escarpment overlooking the valley, especially suggests the *Spirifer marcoui* zone. *Omphalotrochus* also occurs at this point, but it is much more abundant at a somewhat higher horizon, where it is associated with a varied gastropod fauna. A considerable thickness of rocks succeeds, with varying faunas more or less closely related to those below, and it is safe to say that 3,000 feet of sediments are measured above these before the top of the Capitan limestone is reached, the faunas of which do not so strikingly resemble those of the Russian series as is the case with the Hueco faunas. *Productus cora* is conspicuous by its absence, while if *Schwagerina* occurs at all in the American section it is in the lower beds associated with *Spirifer marcoui* and *Omphalotrochus*. Indeed, a considerable portion of the faunas of these lower horizons resembles that of the *Schwagerina* zone. On the other hand, the highest fauna of all (that obtained near the middle of the Capitan limestone) also resembles the *Schwagerina* fauna in the number and variety of its Terebratuloids, Spiriferinas, and Spirifers of the type of *S. lyra* Kut., *S. tibetanus* Dien., etc., of which *S. mexicanus* is an American representative. There are few Terebratuloids and Spiriferinas in the faunas of the Hueco Mountains; they are quite different from those of the Capitan limestone, and the Spirifers also are different. The Producti, especially, of the Hueco faunas are like those of the *Schwagerina* zone. Thus, though the lower faunas found in the Hueco Mountains are throughout quite different from the upper ones found in the Guadalupe Mountains, both have points of strong resemblance in a common fauna, that of the *Schwagerina* zone of eastern Russia. The Russian faunas have peculiarities not found in any of those of the Trans-Pecos region, and of these none is perhaps more striking than the abundance and variety of the Spirifers (especially *S. ufensis* and *S. supracarbonicus*, no representatives of this type being known in Texas), *Spiriferella*, *Martinia* and *Martiniopsis*. *Seminula*, whose abundance seems to be a distinctive feature of nearly all American Carboniferous faunas, still occurs in numbers in the Trans-Pecos. All the upper beds of the latter, 2,000 feet or more, are characterized by the presence at intervals, often in extraordinary abundance, of a large, greatly elongated *Fusulina*, *F. elongata* Shum. And they are marked by the frequent occurrence of large examples of those singular brachiopod genera *Leptodus* and *Richthofenia*. These types seem not to occur in the Russian faunas.

Tschernyschew finds that all the beds whose fauna he discusses, divided by him into zones, of which the highest is the *Schwagerina* zone, underlie the typical Permian of Russia. If this is so, and if the resemblance of the Capitan fauna to that of the *Schwagerina* zone warrants assigning the Capitan limestone to that horizon, the entire Trans-Pecos Carboniferous section would lie below the true Permian.

In a preliminary paper on the Capitan fauna,[1] relying upon its resemblance to those of the Salt Range of India, of the Carnic Alps, and especially of the region about Palermo, in Sicily, faunas which have been called Permian by different authorities, I called that from Texas also Permian, as indeed, its discoverer, Shumard, had done; and, in view of its entire difference from the so-called Permian of the Mississippi Valley, and upon other considerations, even regarded it as upper Permian. Several circumstances leave me still of the opinion that this bed may be Permian. Its fauna is strikingly like that described by Gemmellaro from Sicily, which Tschernyschew ascribes to the Artinsk stage of the true Permian. In some respects the resemblance of the Capitan fauna to that of the *Schwagerina* zone is also striking, but, as already remarked, there is much in the *Schwagerina* horizon that is not found in the Capitan fauna, and much which in western Texas is found only at a much lower horizon. These facts, taken in conjunction with the circumstance that the thickness of the beds comprising all four of Tschernyschew's zones (for his work as the title indicates excludes the fauna of the *Spirifer mosquensis* zone) is considerably under 1,000 feet, while the Texan series is considerably over 4,000 feet, certainly lend a color of probability to the hypothesis that the higher beds in Texas may be younger than the *Schwagerina* zone. It seems probable indeed that all four of Tschernyschew's horizons are represented in the Hueco formation, where the different faunas are not as clearly distinguishable into separate entities as in Russia, the faunas of the Delaware Mountain sandstone and the Capitan limestone being derived from them, but modified by evolution of surviving species, the elimination of some forms and the introduction of others by migration.

Another consideration is that Tschernyschew correlates the Permo-Carboniferous of the Wasatch Range with the Artinsk,

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[1] Am. Jour. Sci., vol. 14, 1902, p. 363.

while I am tentatively placing it at the horizon of the "Permian" of the Grand Canyon section and of the Delaware sandstone of the Guadalupe Mountains. My evidence is not conclusive, but certainly no fauna at all like that of the Capitan is known in Utah underlying the "Permo-Carboniferous," while the Aubrey group, which occurs beneath the "Permian" of the Grand Canyon, probably represents the upper part of the Hueco formation, though it may be partially equivalent to the Delaware Mountain formation.

On the whole, therefore, it seems to me rather more probable that much if not all of the Capitan and Delaware formations is younger than the *Schwagerina* zone. The explanations as to the partial resemblance of the Capitan fauna to the *Schwagerina* fauna called for by this hypothesis, are certainly no more difficult than in the opposite case. Even if these series of rocks are admitted to be younger than the *Schwagerina* zone, however, it does not follow that they correspond to the true Permian, rather than to a horizon not represented in the Russian section; but from the considerations set down above this would appear to be the case.

In even so cursory and incomplete a comparison of the American with the Russian faunas, one feature of the latter is too striking to be entirely neglected. American paleontologists have come to look upon the genus *Archimedes* as diagnostic of our Mississippian series, and to us it comes as an almost startling anomaly that this type is well represented in the upper Carboniferous of Russia. It seems, indeed, to be especially characteristic of the highest beds (the *Schwagerina* zone), from which Tschernyschew cites 4 species, one of them our own *Archimedes wortheni*. No trace of this genus has been observed in any of the Trans-Pecos faunas, yet its occurrence in the Upper Carboniferous of this continent is not entirely unknown, since White cited *Archimedes* associated with an Upper Carboniferous fauna from the Uinta Mountains.[1] Four or 5 years ago I also collected the genus in abundance in the Bingham mining district, Oquirrh Mountains, Utah, associated with a fauna, which is certainly not one of those characteristic of the

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[1] Rept. Geol. Uinta Mountains, etc., 1876, p. 80.

upper Mississippian, and which without much doubt belongs in the Western Upper Carboniferous in the horizon of the Hueconian series (Weber quartzite). Furthermore, being called upon nearly 2 years ago to determine the boundary between the Upper and Lower Carboniferous in northern Arkansas, a careful faunal study led me, as already described, to draw the line at the top of the Archimedes limestone. Thus the genus *Pentremites*, which, equally with *Archimedes*, has been supposed to be infallibly diagnostic of Mississippian time, is found to occur in abundance in the Upper Carboniferous (Pentremital limestone; sparingly in the Kessler), and although *Archimedes* practically dies out in this area with the Archimedes limestone, a few fragments representing it occur in the beds above. It appears, therefore, that even in the Mississippi Valley this striking genus ranges above the top of the Lower Carboniferous, and while only a very scanty representation has thus far been found, unless the Archimedes limestone proves to belong in the Pottsville rather than in the Mississippian, there is no reason to believe that it did not survive in abundance in other regions, as, indeed, proves to be the case.

Tschernyschew also correlates the Russian section with that of the Mississippi Valley. His correlation may be correct, but the Pennsylvanian faunas of the latter area are so widely different from those of our Western States which the Russian ones most closely resemble, that, in the opinion of one who has some acquaintance with both types, a precise correlation is, in our present knowledge, impossible. The beds placed in alignment by Tschernyschew contain faunas so widely dissimilar that it seems an act of temerity to group them together. The evidence for so doing consists in part of the occurrence of certain American species in the Russian faunas, but the identifications, if one may judge by the figures given, in some cases are questionable and in others consist of such long-ranged types that in view of the really small percentage which these forms bear to the entire fauna, the evidence appears of diminishing significance the more critically it is examined.

I should not be understood, however, as expressing a belief that these Western faunas do not in a general way, in part at least, correspond to those of the Mississippi Valley, but personally I know of no instance where a detailed correlation can confidently be made. It is my hope and belief that these relations can be determined with precision, and if it proves that the Russian investigator has had the clearness of vision to discern them aright, all the greater should be his meed, because of the intricacy which the question seems to present.

The opinion has been expressed that the Pennsylvanian faunas of eastern and western United States may belong in different provinces, and that they are probably to some extent equivalent. The belief is tentatively held that the highest of our Western horizons are considerably younger than the highest known invertebrate horizons of the East, those of the Kansas section, for instance, which are characteristic of the so-called Permian of the Mississippi Valley. In spite of the able pens which have traversed this subject, the correlation of these beds is still one of the unsettled problems of the American Carboniferous. If the Capitan fauna is Permian, then certainly that of Kansas is not, for 2 Carboniferous faunas could scarcely have less in common. While it is possible that the so-called Kansas Permian is a provincial phase of the Guadalupian, this is yet to be demonstrated, and it is questionable whether for 2 faunas so essentially unlike, even if proved to have been contemporaneous, the same name could with propriety be used. On the assumption that the Kansas beds are Permian, so closely are they connected, faunally and stratigraphically, with those below, the term Permian must be reduced to denominate a difference not much greater than that between the Burlington and Keokuk, or else most of the Kansas section must be placed in the Permian, a disposition against which there is much evidence. It seems probable that the Kansas Permian represents a faunal development in a distinct province from that of the West, the Western faunas being co-provincial with the typical Permian sea. The equivalence of the Kansas Permian is not to be determined upon the basis of a community of a few slightly differentiated long-lived types, but must be worked out by a consideration of the fauna as a whole and the facies which it receives from the presence of a series of equivalent but probably not equal species.

The Guadalupian faunas are not only widely different from those of Pennsylvanian age in the Mississippi Valley, but they appear to have a distinctly younger facies, biologically considered. So far as the significance of the somewhat hastily reviewed evidence has been grasped, it seems to assign the Kansas faunas to about the horizon of the Hueco formation, placing the entire Guadalupian series, or at all events the Capitan, as a younger evolution, whether the 2 faunas were developed in distinct provinces or in the same.

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THE BLOOD-VASCULAR SYSTEM OF THE LORICATI, THE MAIL-CHEEKED FISHES.

By WILLIAM F. ALLEN.

CONTENTS.

SECTION I. INTRODUCTORY.

I. INTRODUCTION.

The blood-vascular system of fishes is no new subject. It has been carefully worked out for many groups. We have the memoirs of Müller on *Myxine*, T. J. Parker on *Mustelus*, Hyrtl on the roaches, McKenzie on *Ameiurus*, Vogt on *Salmo*, Emery on *Fierasfer*, Cuvier and Valenciennes on *Perca*, and the general account found in Stannius' Anatomy. The object of this paper is to give a fairly complete account of the vascular system of *Ophiodon elongatus* (blue cod); and to make some comparisons with other members of the suborder LORICATI, the mailed-cheeked fishes. In a later paper I hope to go more into detail with the peripheral endings of the vessels in the organs of the viscera and those of special sense, as well as to take up the lymphatics.

This group of fishes is distinguished by the extension of the third suborbital bone across the cheek as a stay to or toward the preopercle. In view of the wide variation in this group, Dr. Gill says (45)[1] that it is not a natural division. He, however, divides this suborder into 8 different families, placing the Scorpænidæ (the rock fishes), as the most generalized, on account of their resemblance in form to the Serranidæ and Sparidæ; and the Cottidæ (the sculpins) are placed as the most specialized. Between these extremes come the family Hexagrammidæ, placed nearer the Scorpænidæ than the Cottidæ. There are, however, many points of resemblance to the Cottidæ to be found in their osteology, visceral organs, nervous and vascular systems.

The subfamilies *Hexagramminæ*, *Ophiodontinæ*, *Zaniolepidinæ*, and *Oxylebiinæ*, given by Jordan and Evermann (45, p. 1864), are very strongly marked. *Ophiodon* and probably *Zaniolepis* are about as closely related to *Scorpænichthys*, a sculpin, as they are to *Hexagrammos*, and should be regarded as types of distinct families.

The following species of fishes were studied.

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[1] All figures in brackets refer to bibliography at the end of the paper.

Family SCORPÆNIDÆ.

Sebastodes flavidus Ayres, yellow-tail rockcod; *S. melanops* Girard; *S. mystinus* J. & G., black fish; *S. auriculatus* Girard, brown rockcod; *S. carnatus* J. & G., flesh-colored rockcod, and *S. nebulosus* Ayres, yellow-spotted rockcod.

Family ANOPLOPOMATIDÆ.

Anoplopoma fimbria Pallas, black cod.

Family HEXAGRAMMIDÆ.

Hexagrammos decagrammus Pallas, sea trout and *Ophiodon elongatus* Girard, blue cod.

Family COTTIDÆ.

Scorpænichthys marmoratus Ayres, cabezon; *Calycilepidotus spinosus* Ayres, and *Enophrys bison* Girard.

For detailed work, *Ophiodon elongatus* was taken as a type. The reason for choosing *Ophiodon* was partly because of its position between the 2 extremes of the suborder, but especially on account of its size (sometimes reaching a weight of 70 lbs.), and the ease with which it can be injected. Every effort has been made toward accuracy. Several specimens of each species compared have been studied, in order to eliminate the error that might come from variation in different individuals of the same species. Notwithstanding, omissions, if not errors, have probably crept in. The drawings, rude as they may be, were all made from a single dissection, with the exception of Pl. I, fig. 1, which is a combination of several dissections.

The material for this paper was collected by Chinese fishermen at Monterey Bay, Cal. The work was done at Stanford University and at the Hopkins Seaside Laboratory, and under the direction of Prof. C. H. Gilbert, to whom I am indebted for many favors and the facilities for research. Also I am under the greatest obligations to Prof. G. C. Price, of Stanford University, for a room at the Hopkins Laboratory; and to Mr. J. C. Brown of the University of Minnesota, for many favors.

II. TECHNIQUE.

1. Injecting Masses.

Nearly every injecting mass and color has been tried, but the most satisfactory, as well as the cheapest, proved to be a gelatin mass, colored with Berlin blue or carmine, and Hoyer's lead chromate yellow gelatin mass; or, for tracing out fine vessels and histological work, a saturated aqueous solution of Berlin blue may be used.

Berlin blue can be purchased in the form of a dried precipitate and this dissolved in water, but a more satisfactory solution is obtained by following the directions of Mayer (54, p. 310). A solution of 10 c.c. of tincture of perchloride of iron, or a saturated solution of ferric trichloride, in 500 c.c. of water is added to a solution of 20 grams of yellow prussiate of potash in 500 c.c. of water. This mixture is allowed to stand for 12 hours. The yellow fluid at the surface is then poured off, the remainder filtered and the filtrate washed with distilled water until the washings come through dark blue. Enough water is then added to completely dissolve the precipitate. This should make about a liter of concentrated solution of Berlin blue.

If a gelatin solution is desired, use from 10 to 20 parts of the Berlin blue solution to one of the gelatin. I usually take 25 grams of gelatin to 100 c.c. of water; heat in the same water bath with 200 or 300 c.c. of the Berlin blue solution. When the gelatin solution is melted, add to it, slowly, the Berlin blue solution; the mixture is then heated until the precipitate, which is usually formed, disappears. Then filter through a flannel. If the mass is to be kept some time, add a little chloral hydrate. For fish vessels it is best to inject the mass as cool as possible.

Hoyer's Yellow Lead Chromate Gelatin Mass (see Lee's Vade-Mecum, p. 304) is a very simple mass to make. Prepare 2 bottles of stock solution; in one, make a saturated aqua solution of potassium bichromate, and in the other a saturated solution of lead acetate. Then soak up 25 grams of gelatin in 100 c.c. of water; heat to melting point in a water bath; add 100 c.c. of the potassium bichromate solution. Afterward heat nearly to the boiling point; add 100 c.c. of the lead acetate solution, and filter through a flannel. It is best to make this mass shortly before using. This mass has a beautiful yellow color, having a very fine precipitate, which easily passes through the fine capillary net-works of the gills, pseudobranchiæ, and retia mirabilia of the eye.

A carmine solution is prepared by mixing some carmine with water; enough ammonia is added to dissolve the carmine, giving it a dark brown color. The mass is then neutralized with acetic acid, and when neutral it will change to a bright red color. If desired to keep for some time, add chloral hydrate. Like the Berlin blue solution it can be injected as it is: or it can be mixed with a gelatin mass in the same proportions.

2. *Apparatus.*

The apparatus consisted of a number of glass cannulas of various sizes, fastened to short, but stout rubber tubes; a 4-oz. rubber syringe, and a ½ oz. rubber syringe. The latter, when connected with a rubber tube and a small glass cannula makes the best kind of a hypodermic syringe.

3. *Mode of Procedure.*

When the arteries and veins are to be injected with different colors, it is best to inject the venous system first. This can generally be accomplished from the *hepatic vein* (Pl. I, fig. 1, Hep.V.). A ligature is placed under the vein and tied loosely: a slit is made in the anterior portion of the liver, and a large cannula attached to a rubber tube is forced cephalad in the vein into the *sinus venosus*. The blood was sucked into the tube, and then blown out; this process was repeated, until the sinus and other vessels were cleared of blood, and the cannula was again inserted into the vein and ligatured. Then the syringe was filled with the yellow injecting mass, but before connecting with the rubber tube, all the air possible should be sucked out of the tube, sinus, and other vessels. With a slow steady stroke the mass is forced into the sinus venosus; from thence through the heart to the gills; through the precava to the jugular and cardinal veins, and usually it would pass through the other hepatic vein and the venous capillaries of the liver, thus filling the portal system. If this fails, the portals can easily be injected from the *posterior mesenteric vein* (Pl. I, fig. 1; P.Mes.-

V.); or, if this vessel is absent, from one of the intestinal veins. If desirable to fill the caudal, neural, and hæmal veins, a separate injection of the *caudal vein* (fig. 1, Cau.V.) is usually required. The entire arterial system can be filled from one of the *gastric arteries* (fig. 1, L.Gas.A.), but an easier and more satisfactory way, especially if the fish has no air-bladder, is to make 2 injections of the *dorsal aorta* at a point marked X (fig. 1), shortly before it penetrates the kidney and posterior to the origin of the cœliaco-mesenteric and subclavian arteries. A cannula the proper size, having a rubber tube attached, was slipped cephalad into the vessel and ligatured. If the aorta is small, the rubber tube and cannula can be used as a blow pipe to help open it up. The syringe is then filled with the Berlin blue injecting mass; as much air as possible is sucked out of the tube and vessels before connecting the tube with the syringe; with a slow, steady movement, the mass is forced cephalad into the aorta, from whence it passes into the carotids, efferent branchial vessels, cœliaco-mesenteric and subclavian arteries, and finally in like manner, from the same place, the aorta is injected caudad, which fills the vessels of the kidney, reproductive organs, body wall, and tail.

In tracing out the small peripheral vessels of the head, fins, and viscera, I have found it very satisfactory to inject alone the head, fins and viscera of a 15 to a 40 pound fish. The head is severed dorsally several inches behind the skull, including the pectoral and ventral fins, being careful not to cut or injure any of the visceral organs. A ventral slit is then made through the entire ventral wall to the vent; the intestine is cut at the rectum, and the entire viscera pulled out with the head. In this manner the fish is cleaned, spoiling very little if any of the flesh, after which the 2 cut ends of the *cardinals* (Pl. I, fig. 1, L. & R.Car.V.), and the posterior end of the *ventral artery* (Pl. II, fig. 12, Ven.A.), if cut, were ligatured. Two injections, as described in the previous paragraph, were made; one from the *hepatic vein*, and the other cephalad from the cut end of the *dorsal aorta*.

In most cases it is best to make the dissections while the material is fresh. As a preserving fluid I find nothing better than formalin; it does not extract colors as does alcohol, and its action toward gelatin is favorable, hardening it considerably. The coats of the eye are fixed in perfect shape, and such delicate organs as the kidneys are quickly hardened, so that one can cut cross-sections with a knife, which is a great help in tracing out the renal-portal system.

If a histological injection is required, slit the *sinus venosus* and wash out the blood vessels, cephalad, from the *dorsal aorta*; then inject with an aqua or thin gelatin Berlin blue mass, or with Hoyer's yellow chromate mass, freshly prepared. The mass is allowed to set and the injected organs are thrown in toto into Müller's fluid, or better still, cut up into small pieces and thrown into any well known fixing fluid that will not extract the colors. Injected material thus fixed can be kept some months in alcohol, but it is best to imbed as soon as possible.

If the bile vessels are to be injected, it can be accomplished by slitting the *ductus choledochus*, near its exit into the intestine or pyloric cæca. A hypodermic syringe filled with the Berlin blue mass is inserted into the duct, toward the gall-bladder, filling first the bladder, then the hepatic ducts, and finally, if successful, the gall-capillaries.

III. HISTORICAL REVIEW.

To Duverney (13),* in 1699, 62 years after the discovery of the blood-vascular system by Harvey, and 38 years after the discovery of the capillaries by Malpighi, belongs the honor of first explaining the structure of the fish heart; and 2 years later (14) he described and figured the circulation in and about the gills of the carp; he erred, however, in finding but one branchial vessel in a branchial arch. Monroe (48) in 1787, was the first to describe correctly the circulation in the gills. He injected the ventral aorta and examined the gill-filaments under a microscope; he also noticed the efferent branchial vessels, uniting to form the carotids, cœliaco-mesenteric, dorsal aorta, and the subclavians, and observed the coronary and other vessels coming from the ventral ends of the efferent branchial vessels; as well as the jugular, portal, and renal-portal systems. According to Müller (50), Albers (1) in 1806, was the first to notice the choroid gland of the eye, and observed that the vessels in the cho-

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* All figures in brackets refer to bibliography at the end of the paper.

roid coat arose from this plexus. The first volume of Cuvier and Valenciennes' great work on fishes (11) issued in 1828, contains a short general description of the circulation of *Perca*, with 2 excellent plates, which show practically all the vessels, including the afferent and efferent pseudobranchial arteries, and 10 years later, Jones (41) carefully described and figured the retia mirabilia of the eye.

About this time marked the beginning of the classical writings of Hyrtl, Müller, Vogt, and Stannius. Between the years 1838 and 1872, Hyrtl published at least 7 different papers on the circulation of fishes, but unfortunately I have had access to only a few of them. Müller (50) tells us that in the first one (30) the author made a microscopical examination of the gill-filaments, and showed that they contained no lymphatic vessels, as had been claimed by some previous investigators. He also explained correctly the course of the blood from the hyoidean artery to the pseudobranchiæ, and from thence to the eye. With Hecht, he noticed the pseudobranchial artery coming from the circulus cephalicus. In 1852, Hyrtl (32) described with considerable detail the arterial system of *Lepisosteus*, and 6 years later the arterial system of the roaches (34). One of the best general works on the circulation of fishes is to be found in part IV of Müller's famous work on Myxinoiden (50), consisting of 130 pages and 5 plates. He takes up almost the entire circulatory system of cyclostomes, selachians, and several teleosts in a comparative way, going into great detail over the blood supply of the pseudobranchiæ, choroid gland, and air-bladder. Vogt's splendid monograph on the Anatomy and Embryology of the Salmon was published in 1845, but unfortunately I could get access only to the plates, of which several were devoted to the adult, and many others to the development of the circulatory system in the embryo. In Stannius' Handbuch der Anatomie der Wirbelthiere (74), there is a brief, but perhaps the best, general description of the circulation in the several groups of fishes; there are, however, no plates. The author does not go into quite as much detail regarding the blood supply of the pseudobranchia, eye, and air-bladder as Müller, but goes into more detail concerning the larger trunks and the vascular supply for the visceral organs.

During the last half century quite a number of important papers have appeared on the circulation of different species of fishes, or confined to the circulation of various organs, and a few are devoted to the embryology and physiology of the blood vessels. First under this head might be mentioned the first volume of Owen (58), which was issued in 1866. The author gives a very good comparative description of the circulation in several groups of fishes. Ten years later Stöhr (75), described the number and arrangement of valves in the conus arteriosus of selachians and ganoids. In 1880, Emery (24) put out his monograph on the genus *Fierasfer*. This volume contains a short, but accurate account of the circulatory system and 2 most excellent colored plates; the first one consists of a figure of the entire arterial system, a similar figure of the venous system, and several figures showing the blood supply in the kidneys; while the other plate is devoted to the blood vessels in the organs. The same year T. J. Parker published a paper, to which I have not had access, on the venous system of the skate, *Raja nasuta* (59). In 1884, McKenzie published a most excellent paper on the catfish, *Amciurus catus* (52). He gives one figure showing the union of the efferent branchial arteries to form the carotids, dorsal aorta, etc., and finds the pseudobranchiæ, though only rudimentary, located on the main internal carotid artery, and not on a branch of the external carotid or hyoidean artery as is the case with bony fishes in general. In Marshall and Hurst's Zoölogy (53), there is one figure and a very good description of the circulation of the dogfish, *Scyllium canicula*. By far the best account that we have of the circulation of selachians is found in T. J. Parker's memoir on *Mustelus* (60), which was published in 1886. It contains 47 pages and 4 most excellent colored plates. The author gives a brief synonymy of the blood vessels, and his methods of investigation. Unfortunately I did not gain access to this valuable paper, until my own work was nearly completed. Mayer (55), in 1888, gives a detailed account of the circulation in the fins of selachians, with 2 colored plates. The author gives the technique employed and favors an aqua solution of Berlin blue for an injection mass. The so-called peripheral lymphatic vessels described by Hyrtl, Müller, and Stannius, he considers as veins. An excellent account of the embryology of the heart and blood vessels was given by Hoffman (39) in 1893. In Vogt and Yung's Anatomie, vol. 2, there is found a brief, but excellent account of the circulatory system of the perch, with 2 colored plates. T. J. Parker (61) in his Zoötomy, 1895, gives the general outline of the circulation in the skate, *Raja nasuta*, with 2 figures, and also a similar description and one figure on the circulation of the cod, *Gadus morrhua*. In the first few pages of Allis' paper on *Amia* (3), there is a detailed account of the circulation in the head region, illustrated by several beautiful colored plates. To Jordan and Evermann (45) in 1898, we are indebted for a systematic arrangement of the fishes and fish-like vertebrates of North America. In 1900, Allis (4) published a complete account of the development of the pseudobranchial circulation in *Amia*, and lastly, Brünning (10) in the same year was the first to work out in any detail the physiology of the blood vascular system of fishes. To this list might be added the general comparative anatomies of Gegenbour (26 and 27) and Wiedersheim (86 and 87).

SECTION II. TEXT.

IV. GENERAL SURVEY OF THE BLOOD VESSELS IN OPHIODON.

Since the blood of a fish passes around in a circle, it matters but little where we begin. A simple glance at Pl. I, fig. 1, will give an idea of the general course of the blood. The entire venous blood is poured into the *sinus venosus* (Pls. I and II, figs. 1 and 12; Sin.Ven.), through 6 large sinus-like vessels. From the rear come the *hepatic veins* (Pls. I and II, figs. 1 and 12; Hep.V.), which through the capillaries of the liver receive the *portal veins* (Pl. I, figs. 1, 6, and 11; L. and R.Por.V.), bringing the venous blood from the viscera; and the *ventral veins* (Pl. I, fig. 12; L. and R.Ven.V.) conveying the blood from the ventral or pelvic fins and the body walls. From either side, the sinus venosus receives 2 large lateral trunks. The posterior ones or *subclavian sinuses* (Pl. II, fig. 12; Sub.S.) are the smaller, containing venous blood from the outer or abductor muscles of the pectoral fins; and the anterior or larger ones are the *precaval veins* or *ductus cuvieri* (Pl. II, fig. 12; Prec.V.), which receive the venous blood from the rest of the body. Close to the sinus venosus the right precava receives the *inferior jugular vein* (Pls. I and II, figs. 1 and 12; I.J.V.), returning the venous blood from the branchial muscles and the pharynx. Passing dorsad around the œsophagus, each precava arises at the ventral surface of the head kidney from 2 large trunks; the cephalic vessels or *jugular veins* (Pls. I and II, figs. 1, 5, and 12: R. and L.J.V.) convey the venous blood from the face, nose, eyes, brain, and dorsal branchial muscles and their arches; and the caudal vessels or *cardinal veins* (Pl. I, figs. 1 and 5: R. and L.Car.V.) vary greatly in length and in size. The short left cardinal returns blood only from the left head kidney; while the large right cardinal arises in the posterior end of the kidney and through the *renal veins* (Pl. I, figs. 1 and 10: A. and E.Ren.V.) receives blood from the *caudal vein* (Pl. I, figs. 1 and 10; Cau.V.) coming from the tail in addition to collecting blood from the thoracic walls, reproductive organs, and viscera.

From the sinus venosus, the blood passes into the *auricle* or *atrium* (Pls. I and II, figs. 1 and 12; Aur.), through the *ventricle* (Pls. I and II, figs. 1 and 12; Ven.) into the *bulbus arteriosus* (Pls. I and II, figs. 1 and 12; B.Art.), from whence it is forced through the *ventral aorta* or *branchial artery* (Pls. I and II, figs. 1 and 12: V.Ao.) into 4 pairs of *afferent branchial arteries* (Pls. I and II, figs. 1 and 12; A.Br.A.), (the third and fourth pairs, however, arise as one trunk, but soon divide), which run in the posterior grooves of their corresponding arches. These vessels exhaust themselves in numerous *afferent filament arteries* (Pl. I, fig. 2; A.Fil.A.), which pass along the inner edge of each branchial filament and which are collected on the opposite or outer side by the *efferent filament arteries* (Pl. I, fig. 2; E.Fil.A.), after having passed through a fine capillary network, where the blood is purified by the oxygen held, physically, in the water. These efferent filament arteries, containing pure arterial blood reunite, forming the *efferent branchial arteries* (Pls. I and II, figs. 1, 5, and 12; E.Br.A.), which run parallel, but cephalad to the afferent branchial arteries. From the ventral ends of these efferent vessels are given off the *hyoidean artery* (Pls. I and II, figs. 1 and 12; Hyo.A.) for the hyoid arch and tongue, and which anastomoses with the facialis-mandibularis branch of the external carotid forming the mandibular artery; the *pharynx artery* (Pl. II, fig. 12: Phar.A.) for the ventral branchial muscles, from which the *coronary artery* (Pls. I and II, figs. 1 and 12: Cor.A.) arises: the *ventral artery* (Pls. I and II, figs. 1 and 12; Ven.A.) for the ventral or pelvic fins and the ventral body walls; and several smaller arteries, which will be described in detail further on. Dorsally the efferent vessels send off anteriorly the *common carotid arteries* (fig. 1; C.Car.A.), which supply the face, orbit, nose, and brain; and posteriorly the efferent branchial vessels unite in forming the *cœliaco-mesenteric artery* (Pl. I, figs. 1 and 5; Cœ.Mes.A.) for the viscera; the *subclavian arteries* (figs. 1 and 5; Sub.A.) for the pectoral fins: and the *dorsal aorta* (figs. 1 and 5, D.Ao.) for the body walls, tail, kidney, and reproductive organs. The union of these efferent branchial vessels to form the internal carotids anteriorly and the dorsal aorta posteriorly, forms what is known as the *circulus cephalicus*.

V. HEART.

This organ, which is inclosed in the triangular cardiac space, lies in the ventro-median line directly cephalad of the pectoral arch. The pharnyx forms the roof of this cavity, the thick sternohyoideus muscle the floor, and together with the pharyngo-clavicularis internus muscles it makes up the lateral walls: while the aponeurotic membrane forms the posterior wall that separates the cardiac cavity from the visceral cavity. This chamber is lined with the pericardium, which, like the peritoneum, consists of a parietal and visceral layer; the former lines the cavity and the latter loosely envelops the heart, being attached anteriorly to the ventral aorta in the region of the first afferent branchial vessels and posteriorly to the dorsal and ventral wall of the precava. The space between the parietal and visceral layers is known as the outer pericardial cavity or pericardial lymphatic sinus, for it is in direct communication with the lymphatics; while the space between the heart and the visceral layer is known as the inner pericardial or pericardial cavity proper. No connections were noticed between these 2 cavities.

As in the other vertebrates the heart is the center of activity, however, it contains only venous blood. The heart proper consists of 2 chambers: a dorsal one, the auricle, and a smaller ventral one, the ventricle. The entering blood comes into the auricle posteriorly, from the thin-walled sinus venosus, from whence it is forced ventrad into the ventricle and then out anteriorly into the elastic bulbus arteriosus.

Sinus Venosus (Pls. I, II, and VI, figs. 1, 12 and 39; S. Ven. and Sin. Ven.).—When inflated the dimensions of this thin-walled sinus are about equal. In a 40 lb. Ophiodon this chamber measured 38 mm.[1] in length from the entrance of one precaval vein to the other, 32 mm in breadth from the sinu-auricular valves to the entrance of the hepatic veins, and 28 mm. in height at the center. The large sinus-like vessels emptying into this sinus have their inner edges reflected inward in the form of flaps, which tend partly to close the openings in case of a reverse current. In a like manner the walls of a sinus venosus, after having united with the outer connective tissue layer of the auricle, are reflected inward to form the *sinu-auricular valves* (Pl. VI, fig. 39; S.A.V.). Some fishes are said to have a dorsal and a ventral flap, but in *Ophiodon* they have become fused, forming a continuous circular flap, which decreases the size of the sinu-auricular opening by at least one-half.

Auricle (Text-figs. 1 and 2; Pls. I, II, and VI, figs. 1, 12, 39 and 40; Aur.).—This triangular, saddle-shaped reservoir, convex above and concave below, is much larger than the ventricle, when inflated. It extends over three-fourths of the ventricle; its anterior apex extends cephalad over the bulbus arteriosus some little distance, and posteriorly the auricle ends in 2 lateral horns. In this specimen the auricle measured 34 mm. in length, from its apex to the sinu-auricular valves, and if the posterior horns were included, the length would have been increased by at least 10 mm. The greatest width is in the neighborhood of the posterior horns, where it is 40 mm., and the greatest height amounted to something like 22 mm. The walls of this chamber consist of 2 layers, an outer coat of connective tissue

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[1] All measurements pertaining to the heart were taken from a 40 lb. Ophiodon's heart, which had previously been injected with a gelatin mass and hardened in formalin.

(Text-figs. 1 and 2, and Pl. VI, fig. 39; C.T.) and an inner coat composed of muscle bands, the *trabeculæ carnæ* (Pl. VI, fig. 39; T.C.A.). These muscle bands run in every direction, but mostly dorso-ventrad, and between these bands there are large blood cavities, which increase in size toward the central cavity,

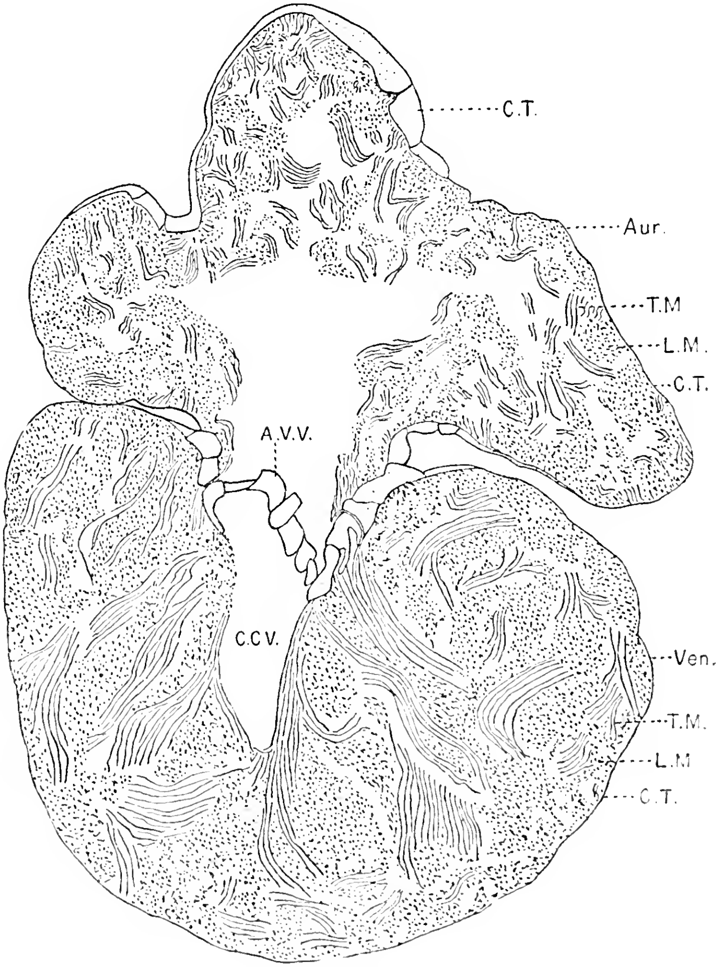

Fig. 1.

the muscular layer becoming more and more compact toward the surface. The central cavity occupies a large portion of the auricle and is continued into the posterior lobes. Penetrating the floor of the auricle, a little caudad of the center, is the *auriculo-ventricular opening* (Pl. VI, fig. 39: A.V.O.), through which, by the contraction of the trabeculæ of the auricle, the blood from the auricle is forced into the ventricle. In order to prevent a back-flow of blood, this passage can be entirely closed by 2 *auriculo-ventricular valves* (Pl. VI, figs. 39 and 40; and Text-fig. 1; A.V.V.), respectively anterior and posterior in position and which when closed appear like 2 inverted cups from the auricle side, having their inner edges free. These valves are formed by the union and a thickening of the outer layer of connective tissue from the auricle and the ventricle.

Ventricle (Text-figs. 1 and 2; Pls. I, II, and VI, figs. 1, 12, 39 and 40; Ven.).—The ventricle, which is 42 mm. long by 27 mm. wide in this specimen, is shaped something like a 4-sided pyramid. Beginning bluntly, it gradually increases in width and then rapidly tapers down into a posterior apex. The ventricle has one more layer than the auricle. Outside is the

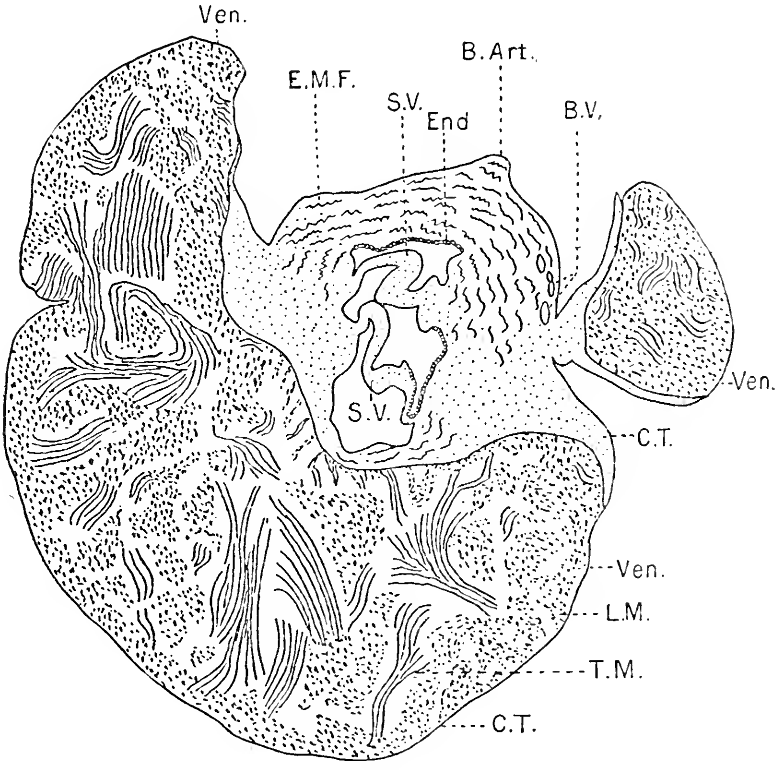

FIG. 2.

connective tissue layer (Text-figs. 1 and 2, and Pl. VI, fig. 39, C.T.), which is continuous with the corresponding layer of the auricle and where such union takes place, the layer becomes much thicker (see Text-fig. 1). The *trabeculæ carnæ* of the ventricle (Pl. VI, fig. 40; T.C.V.) resemble the trabeculæ of the auricle close to the outer connective tissue layer, the blood cavities being very small. In addition to the 2 layers of the auricle, the ventricle has a thick *muscular layer* (Pl. VI, fig. 40; M.L.) between the trabeculæ carnæ and the outer connective tissue layer, containing no blood spaces. The *central cavity of the ventricle* (Pl. VI, figs. 39 and 40; C.C.V.), which runs close to dorsal wall, is much smaller than the central cavity of the auricle. The anterior end of this cavity is continuous with the posterior end of the bulbus arteriosus, which represents the well developed *conus arteriosus* (Pl. VI, fig. 40; C. Art.) of the Elasmobranchs and Ganoids. The entrance into the conus arteriosus is guarded by 2 *semi-lunar valves* (Text-fig. 2 and Pl. VI, fig. 40; S.V.), dextrad and sinistrad in position and having their inner margins free. These valves are similar to the auriculo-ventricular valves, except that each valve has 2 cephalic processes, which continue along the dorsal and ventral walls of the bulbus arteriosus. A reverse current, caused by a retraction of the elastic walls of the bulbus, would entirely close these valves, allowing no blood to return to the ventricle.

Bulbus Arteriosus (Pls. I, II and VI, figs. 1, 12 and 40, and Text-fig. 2; B. Art.). — After leaving the ventricle the bulbus rapidly increases in diameter and then gradually tapers down into the *ventral aorta* or *branchial artery* (Pls. I. and II, figs. 1 and 12; V.Ao.), which gives off the paired afferent branchial vessels to the gills. The walls of the bulbus are quite thick and the internal layers are thrown into *longitudinal ridges* or *folds* (Pl. VI, fig. 40; L.F.). The bulbus is richly supplied with blood vessels, which will be described later on.

Microscopical Structure of the Heart (Text-figs. 1 and 2). — A transverse section through one of the auriculo-ventricular valves (Text-fig. 1) shows us that the outer connective tissue layer is greatly thickened in the dorsal portion of the auricle and at the union with the same layer of the ventricle. As in other vertebrates the muscle fibers are striated and run in all directions, but for the most part they can be grouped under the head of *longitudinal muscle fibers* (Text-fig. 1, L.M.) and *transverse muscle fibers* (Text-fig. 2, T.M.). At various places the muscle fibers penetrate the connective tissue layer and very often fibers from the auricle would pass entirely through this layer into the ventricle. The auriculo-ventricular valves are merely a portion of the combined outer connective tissue layer, having their inner margins free, but having their outer edges securely bound down by muscle fibers. About the only difference in structure between the auricle and the ventricle, aside from the relative sizes of their central cavities, is the difference in the density of their muscle fibers. In the ventricle the blood cavities are very small, while in the auricle they are of considerable size, but growing smaller peripherally, and in the ventricle these cavities give place entirely to muscle fibers, peripherally. Cephalad in the ventricle the connective tissue gradually increases about the central cavity, marking the beginning of the conus arteriosus. In 2 places folds of connective tissue pass entirely through the central cavity or conus as it is at this place. They are the semi-lunar valves (Text-fig. 2, S.V.). In places can be seen traces of *elastic muscle fibers* (Text-fig. 2, E.M.F.) and *round endothelium cells* (Text-fig. 2, End.). While it is not the purpose of this paper to demonstrate the presence or absence of a layer of endothelium lining the central cavity of the heart, it may be said, however, that my sections did not show anything that I could positively identify as endothelium, until the origin of the conus was reached; nevertheless a silver impregnation would have doubtless revealed its presence. The walls of the bulbus are formed from 3 coats. The external coat, *tunica externa* or *adventitia* presents no peculiarities; it is composed of longitudinal bundles of connective tissue, in which run the main nutrient vessels. Next comes the *tunica media* or middle coat, which is very thick and forms the longitudinal folds shown in fig. 40, which decrease in height as you go toward the ventral aorta. This tunic is constructed out of circular muscle fibers, in which run many white elastic fibers. The internal coat or *tunica interna*, which is made up of a longitudinal network, is bounded internally by a layer of large round endothelial cells.

VI. PERIPHERAL DISTRIBUTION OF THE ARTERIES.

1. *Branchial Arteries.*

As has already been stated in the paragraph on the general survey of the blood vessels, the *afferent branchial arteries* (Pls. I and II, figs. 1 and 12; A.Br.A.) are paired vessels, which convey the venous blood from the *ventral aorta* or *branchial artery* (Pls. I and II, figs. 1 and 12; V.Ao.) to the branchial filaments.[1] They arise as 3 paired trunks from the ventral aorta. The most cephalic pair supply the filaments of the first branchial arches; the second pair the filaments of the second branchial arches; and the third pair soon divide, the anterior forks supplying the third pair of branchial arches and the posterior forks, the last or fourth pair of branchial arches.[2] All of these vessels, which very closely resemble one another, run in the grooves of their respective arches and gradually exhaust themselves by giving off numerous afferent filament arteries throughout their entire dorsal course.

The *Afferent Branchial Filament Vessels* (Pl. I, fig. 2: A.Fil.A.) of 2 adjacent filaments arise as paired vessels, and running in a caudal direction along the inner or hypothenuse margins of their respective filaments, gradually exhaust themselves in numerous *afferent filament cross-vessels*, which are only about 60 μ apart. Proximally these vessels attain a considerable length, but gradually decrease in length distally. Each cross-vessel terminates in a dorsal and a ventral vessel, from which the *filament capillary network* (Pl. I, fig. 2: Fil. Net.) arises. This network lies in a dorso-ventral plane in-

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[1] A gill or *holobranch* is composed of a double row of filaments or 2 *hemibranchs* attached to the concave or posterior side of each branchial arch. These filaments have the form of right-angled triangles, attached by their short sides to the arches and the hypothenuse sides of each pair face one another. Each pair of filaments is not separated by a cartilaginous rod as is the case with the Elasmobranchs, but they usually overlap one another to some extent at their bases.

[2] This appears to be the normal arrangement among the Teleosts; while in the skate one trunk may supply several branchial arches, and in the ratfish (*Hydrolagus*), I have observed that the ventral aorta gives off a pair of vessels for each pair of branchial arches.

closed in a vascular plate[1] and is separated from the current of water passing between the gills by a thin membrane. By osmosis the carbon dioxide from the blood is exchanged for the oxygen held in the pores of the water. In a like manner the pure blood is collected into a pair of dorso-ventral vessels, which unite, forming a short *efferent filament cross-vessel.* These vessels in turn form the *efferent branchial filament arteries* (Pl. I, fig. 2; E.Fil.A.), which run cephalad along the outer margins of the filaments and which in turn empty into and form a common trunk, running in the posterior groove of each branchial arch, namely, the efferent branchial artery.

These *efferent branchial arteries* (Pls. I and II, figs. 1, 2, 5, and 12; E.Br.A.) very closely resemble one another. They run parallel, but cephalad to the afferent branchial vessels: beginning ventrally they increase in size dorsally. For the most part the efferent filament arteries are poured directly into the main efferent branchial trunks, but dorsad and ventrad they empty into a branch of that vessel. The ventral branch takes its origin from paired vessels, which lie immediately caudad and to either side of the large efferent branchial trunk. They receive first the most ventral pair of efferent filament arteries; then in their dorsal course take up in succession from either side the several following efferent filament arteries, and after having received 20 or 30 such vessels, unite, forming a short trunk, which empties into the main efferent branchial trunk from the rear. In like manner the dorsal branch arises as a paired vessel and returns the blood from several of the most dorsal fiaments. There is also a gradual variation in the point where the various efferent branchial arteries leave their respective branchial arches. The first or most anterior efferent vessel follows along the posterior edge of the cerato- and epibranchials some little distance beyond the dorsal-cephalic bend; while the fourth or posterior efferent branchial vessel leaves the cerato-branchial a little below the dorsal-cephalic bend; and the efferent branchial vessels of the second and third branchial arches come in midway between these extremes, forming a regular series of intergradations. Ventrally the first, second

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[1] Each branchial filament is divided up into numerous parallel vascular plates or lamellæ, which lie in dorso-ventral planes.

and third efferent branchial arteries on one side anastomose with the corresponding trunks of the opposite side. From either side of the ventral point of union of the first pair of efferent vessels, a large *hyoidean artery* (figs. 1 and 12, Hyo.A.) is given off to the hyoid arch and mandibular region. The ventral points of union of the second and third pairs of efferent branchial arteries mark the source of the *ventral artery* (Pls. I and II, figs. 1 and 12; Ven.A.); and the *pharynx artery* (Pl. II, fig. 12; Phar.A.) may arise form either of the third efferent branchial arteries. From the dorso-cephalic surface of the first pair of efferent branchial vessels, the 2 *common carotid arteries* (Pl. I, figs. 1 and 5; C.Car.A.) are given off cephalad; continuing dorso-caudad, the first efferent trunk unites with the second to form the *first* or *anterior epibranchial artery* (Pl. I, fig. 5; Epbr.A.$_{(1)}$), and in like manner the third and fourth efferent branchial vessels unite to form the *second* or *posterior epibranchial artery* (Pl. I, fig. 5; Epbr.A.$_{(2)}$). The epibranchial vessels on one side unite with the corresponding trunks on the opposite side, forming a *common chamber* (Pl. I, fig. 5; C.C.), which lies in a median line ventrad of the basi-occipital. This chamber is the source of several large trunks: the *dorsal aorta* (Pl. I, figs. 1 and 5; D.Ao.) arising from the left posterior dorsal corner; the *cœliaco-mesenteric* (Pl. I, figs. 1 and 5; Cœ. Mes.A.) below and to the right; and the *common subclavian trunk* (Pl. I, fig 5) lies above the aorta and the cœliaco-mesenteric artery. In one case the subclavians were seen to arise separately. The left one had its origin in the same place as the common subclavian trunk, and the right one came from the cœliaco-mesenteric artery.

2. *Arteries Arising From the Ventral Ends of the Efferent Branchial Arteries.*

First under this head might be mentioned the 2 little *hyo hyoideus inferior arteries* (Pl. II, fig. 12; Hys.A.), which arise from the cephalic surface of the first efferent branchial arteries just before they unite ventrally. These vessels run cephalad a short distance and then spread out laterad over the dorsal surface of their respective muscles.

Hyoidean Arteries (Pls. I and II, figs. 1 and 12: Hyo.A.). — A short distance above the source of the inferior hyo hyoideus arteries, 2 large hyoidean arteries are given off to the hyoid arch and the adjacent region. After reaching the hyoid arch from the inside, a little behind the hypohyals, the main trunk runs along the dorsal surface of the cerato- and epi-hyals; making a dorsal bend in front of the interhyal it crosses under the preopercular, and after passing through a foramen, which is formed by the symplectic, hyomandibular, preopercle, and quadrate, anastomoses with the *facialis-mandibularis artery* (Pl. I, fig. 1; F.Man.A.). In the embryo the hyoidean artery probably furnished the entire blood for the pseudobranchia; the current of blood in the facial-mandibular artery was dorsad toward the carotids. Also in the adult it would be possible for the blood from the hyoidean artery to flow dorsad in the facial-mandibular artery as well as ventrad, however, since the facial-mandibular is a much larger artery than the hyoidean, it is not probable that much of the blood from the hyoidean artery runs counter to the current of the facial-mandibular artery. It also might be possible at times for the blood in the hyoidean artery to flow ventrad, that is toward the efferent branchial artery. From Müller's (50), Stannius' (74), and Emery's (24) descriptions, one would infer that the hyoidean artery in most bony fishes supplied the pseudobranchia, but in *Ophiodon* the blood supply for the pseudobranchia, which will be considered later, comes from a branch of the external carotid artery.

The first branch to be given off from the hyoidean artery is the *lingual artery* (Pl. II, fig. 12; Lin.A.). This vessel leaves the hyoidean artery close to the efferent branchial artery, shortly before the hyoidean artery reaches the hyoid arch, and each lingual artery runs cephalad along the ventral surface of the glossohyal. Immediately after the hyoidean artery reaches the hyoid arch it gives off the *geniohyoideus artery* (Pls. I and II, figs. 1 and 12; Ghs.A.) to the geniohyoideus muscle. One of these arteries is much longer than the other; sometimes it is the right and again it is the left. In the specimen from which fig. 12 was drawn, the right artery was the longer; it passed entirely around to the outer ventral surface of the ceratohyal and then curved cephalad, passing obliquely along the ventral surface of the right geniohyoideus muscle and above the right hyohyoideus inferior muscle. When the median line between the 2 geniohyoideus muscles is reached this vessel bifurcates, one branch running along the ventral surface of each geniohyoideus muscle. Both of these forks supply also the intermandibularis muscle. The short geniohyoideus artery, which is the left one in this specimen, supplies only the posterior part of the left geniohyoideus muscle. The largest of the branches of the hyoidean artery is the hyoid arch artery proper, which has been designated as the *branchiostegal artery* (Pls. I and II, figs. 1 and 12; Br.O.A.). This vessel is given off a little cephalad of the interhyal and runs along the outer ventral edge of the epi- and cerato-hyals. In the region of each branchiostegal ray an artery is given off ventrad to supply the hyohyoideus superior muscles. In *Scorpænichthys* one branchiostegal artery does not supply all of the superior hyoideus muscles. Three or 4 such vessels pass over the outer surface of the epi- and cerato-hyals and supply from 1 to 3 hyohyoideus superior muscles; the last one evidently corresponds to the single branchiostegal artery of *Ophiodon*.

What might be called the *thyroid artery* (Pl. II, fig. 12; Thyr.A.) arises either from the second right or the second left efferent branchial artery. In Fig. 12 it arises from the second right efferent artery, flows cephalad under the ventral aorta and anastomoses with the first efferent branchial artery. Along its short course 2 or 3 small branches could be traced to the thyroid gland, one of them supplying also the second left obliquus ventralis muscle.

Pharynx Artery (Pl. II, fig. 12; Phar.A.).—This vessel may have its source from the third left or the third right efferent branchial artery. In the specimen from which fig. 12 was drawn it arose, caudad, from the third right efferent branchial vessel and, passing obliquely over the ventral aorta it bifurcates in the region of the combined afferent trunk of the third and fourth branchial arches. The smaller *right pharynx artery* (Pl. I, fig. 12; R.Phar.A.) supplies the right side of the pharynx, the transversus ventralis muscle, and the right pharyngo-clavicularis externus and internus muscles; while the larger *left pharynx artery* (Pl. II, fig. 12: L.Phar.A.) supplies the pharynx and similar muscles on the left side. Soon after the left pharynx artery leaves the main stem it gives off the large *coronary artery* (Pls. I and II, figs 1 and 12; Cor.-A.) for the heart. For some little distance this vessel runs along the dorsal surface of the ventral aorta and then divides into a dorsal and a ventral trunk. The *dorsal coronary artery* (Pl. II, fig. 12; D.Cor.A.) continues along the dorsal surface of the ventral aorta and bulbus arteriosus to the heart as the principal vessel. Usually this vessel bifurcates in the region of the conus arteriosus, one branch penetrating directly into the muscular layer of the ventricle, while the other is a superficial vessel, distributing itself over the dorsal surface of the ventricle; or sometimes both may be superficial vessels. It is probable that these vessels also supply the auricle, although I have never been able to trace them further than the ventricle. Each of these vessels gives off a small artery, which encircles the bulbus and anastomoses on the ventral side with the ventral coronary artery, and from this circular artery several small vessels are given off to the bulbus and the ventricle. The *ventral coronary artery* (Pl. II, fig. 12; V.Cor.A.), which is much smaller than the dorsal vessel, also runs caudad in the outer coat of the ventral aorta, but it supplies only the ventral walls of the ventral aorta and the bulbus. None of its branches reaches the ventricle. In *Scorpænichthys* the pharynx arteries arise as separate arteries from the second pair of efferent branchial arteries, and the coronary artery comes from the left pharynx artery, close to its point of origin from the efferent branchial vessel.

The Ventral Artery (Pls. I and II, figs. 1 and 12; Ven.A.) is the largest of any of the vessels arising from the ventral ends of the efferent branchial arteries. In *Ophiodon* this vessel has its origin from the ventral union of the second and third pairs of efferent branchial arteries. This does not appear to be the common arrangement among other bony fishes; in *Hexagrammos*, *Scorpænichthys*, and *Sebastodes* the ventral artery has its source from the second pair of efferent branchial vessels. Continuing caudad along the ventral surface of the pericardial cavity a little to the right of the median line, the ventral artery gives off numerous branches to the sternohyoideus muscle. In the specimen from which fig. 12 was drawn, a vessel was noticed branching off to the left, passing horizontally under the ventricle, and terminating on the left precaval vein in the neighborhood of the left subclavian sinus. Directly caudad of this vessel and a little cephalad to the crossing of the sinus venosus, the ventral artery sends off a pair of vessels to the ventral muscles of the pectoral fin. Each of these *hypobranchial arteries* (Pl. II, figs. 12 and 14; Hypobr.A.) runs a short distance caudad between the sternohyoideus and the pectoral profundus adductor muscle, and then curves slightly dorsad, passing between the inner surface of the coracoid and the pectoral profundus adductor muscle, giving off at least two branches to the inner surface of the muscle; then curving slightly ventrad, penetrates the basal canal of the pectoral rays,[1] and anastomoses in this canal with the *internal subclavian artery* (2) (Pl. II, fig. 14; I. Sub.A.$_{(2)}$), but before entering this canal the hypobranchial gives off a dorsal branch which passes between the pectoral profundus muscle and the brachial ossicles, supplying the inner surface of the muscle. Continuing caudad, the ventral artery passes under the sinus venosus between the pelvic bones, giving off arteries to the body wall, the ventral or pelvic fin muscles, and the ventral rays. The first constant artery of any size to be given off from the ventral artery after it reaches the ventral fin musculature is one which comes out ventrad in a median line to the outer surface of the protractor muscle of the pelvic arch, where it divides at nearly right angles, one branch supplying the left, the other the right protractor muscle of the pelvic fins and the very large abductor muscle of the ventral spine (fig. 12: Ab.V.S.). At various intervals, usually alternating with the veins, the *ventral intercostal arteries* (Pl. II, fig. 12; V.Intc.A.) are given off between every alternate pair of myotomes, and they anastomose with the corresponding dorsal intercostal arteries. The ventral artery

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[1] Each pectoral fin ray consists of 2 separate halves, which are concave inside and convex outside, and where their bases overlap the brachial ossicles in their attachment to the shoulder-girdle, there is formed a rather large canal at the base of the pectoral fin.

also sends off several branches to the other abductor and adductor muscles, and shortly before the pelvic bones become united posteriorly, the ventral artery makes a short dorsal bend and bifurcates at right angles, one branch going to the basal canal of the right ventral fin rays and the other to the left. Each terminal branch of the ventral artery exhausts itself by giving off a branch to the core of each ray; proximally this vessel runs in the center of the cavity, but soon divides, one branch continuing caudad along the right side of the cavity, the other the left. Usually from the left branch of the ventral artery, but often from the right, a median vessel is given off caudad, which passes along the ventro-median line between the 2 great lateral muscles and exhausts itself in numerous intercostal arteries.

This series of complicated vessels arising from the ventral ends of the efferent branchial arteries and anastomosing with a trunk of the subclavian artery may be comparable to the vessels described by Müller (pp. 36 and 37) as epigastrische Arterien, and the ventral artery or ramus epigastricus decendens of Müller may be analogous to the mammaria interna of mammals.

3. *Carotid Arteries.*

The short *common carotid arteries* (Pl. I, figs. 1 and 5; C.Car.A.) arise from the dorsal-cephalic corner of the first efferent branchial arteries, and passing cephalad a short distance, about 1 cm., divide into the large external and internal trunks.

(*a*). *External Carotid* or *Carotis Posterior Artery* (Pls. I and II, figs. 1, 5 and 15; E.Car.A.). — This vessel at once makes a dorsal-cephalic curve, passing through a foramen formed by a lateral process of the prootic, in company with, but directly below the jugular vein. Leaving this canal with the infraorbitalis or truncus buccalis-maxillo mandibularis and just ventrad and caudad of the external jugular vein, the external carotid passes over the dorsal edge of the hyomandibular, along the posterior border of the orbit, and then runs ventro-caudad beneath the levator muscle of the palatine arch and the adductor mandibulæ muscles. It passes along the inner side of the metapterygoid, and after receiving the hyoidean artery comes to the outer surface through a foramen between the symplectic, hyomandibular, preopercular, and quadrate bones. This combined vessel, which may be designated as the *mandibular artery* (Pl. 1, fig. 1; Man.A), makes a sharp cephalic bend, passing over the outer surface of the quadrate bone and then curving inward around it to the inner surface of the mandible, where it terminates in 2 branches, which supply the adductor mandibulæ muscles. The main branch runs along the inner dorsal surface of the bone, while the smaller branch supplies the ventral portion of the muscles.

Along its ventro-cephalic course the external carotid sends off many branches in the facial region and receives one. The first vessel to be given off is the *sclerotic-iris artery* (Pl. II, fig. 15; Scl.Ir.A.). This rather small vessel arises from the dorsal surface of the carotid immediately after it leaves the canal formed by the prootic process. Close to its source the sclerotic-iris artery gives off caudad the most *anterior cranial cavity artery* (Pl. II and III, figs. 15 and 24; C.C.A.), which penetrates the skull through the middle and the largest of the prootic foramina, along the dorsal surface of the roots of the V nerve, and follows up the anterior surface of facialis portion of the ramus lateralis accessorius to supply the adipose tissue in the anterior portion of the cranial cavity. The main trunk, however, continues cephalad a short distance along the outer surface of the prootic dorsad of the gasserian ganglion, and here divides, one branch, the *sclerotic artery* (Pl. II, fig. 15; Scl.A.) continues cephalad, but laterad to the truncus supraorbitalis or ramus ophthalmicus and the orbito-nasal vein. When the orbit is reached, instead of curving inward around the eye with the nerve and vein, it continues in a straight line over the dorsal surface of the eyeball in company with the sclerotic branch of the truncus supra-orbitalis and the sclerotic vein, to supply the adipose tissue surrounding the dorsal surface of the sclerotic coat. The other branch is the *iris artery* (Pls. II and III, figs. 13, 15 and 19; Ir.A.), which enters the skull through a foramen bounded by the dorsal process of the parasphenoid, the alisphenoid, and the prootic. Together with the ciliary nerve and internal jugular vein it passes cephalad out of the skull through the large olfactory-optic foramen, then curving laterad in company with the ramus ciliaris longus and the iris vein it crosses under the orbito-nasal vein and the truncus supra-orbitalis, passing between the superior and external rectus muscles, gives off a branch to the latter (Pl. II, figs. 13 and 15; Ex.R.A.). Then running laterad across the posterior dorsal surface of the eyeball it penetrates the sclerotic coat in its median line, and continuing laterad in the silver layer of the choroid until the iris is reached, where, with the ramus ciliaris longus, it bifurcates into 2 ventral vessels, which supply at least the dorsal half of the iris. The normal arrangement of the iris vessels is first the iris vein, then the ramus ciliaris longus, and finally the iris artery, but in several cases I have observed the artery curving cephalad and passing between the nerve and the vein.

The second vessel is given off a little below the sclerotic-iris artery; and after making a rather sharp caudal curve terminates in the levator arcus palatini muscle. The next vessel is the *facialis-maxillaris artery* (Pl. I, fig. 1; F.Max.A.) which arises cephalad from the external carotid in the region of the orbit, and passes obliquely over the external jugular vein and the ramus mandibularis or the ramus maxillaris inferior, where it gives off a large ventral branch, the *facial artery* (Pl. I, fig. 1; F.A.), for the adductor mandibulæ muscles. This branch runs along the lateral surface of the deeper portion of the adductor mandibulæ, giving off numerous branches to the adductor muscles, but does not follow the nerve to the mandible. The main portion of the facialis-maxillaris artery proceeds along the floor of the orbit in the adductor arcus palatini muscle, to which it gives off numerous branches, and when the level of the nasal sac is reached it receives a much larger artery from the *orbito-nasal artery* (Pls. I and III, figs. 1 and 17; O.N.A.), which is a branch of the internal carotid artery.[1] This combined vessel continues in a cephalic direction, supplying the region directly

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[1] McKenzie (52, p. 427) mentions the crossing of the branches of the external and internal carotids in the neighborhood of the nasal sac, in *Ameiurus* but nowhere have I met with the statement of their union.

behind the maxilla, and sends one branch ventro-caudad along the outer ventral surface of the adductor mandibulæ muscle.

As the external carotid artery passes behind the metapterygoid it gives off the large *pseudobranchial* or *afferent pseudobranchial artery* (Pl. I, fig. 1; Ps.A.) caudad to the pseudobranchia. Passing behind the hyomandibular, the pseudobranchial artery gives off a good-sized vessel dorsad for the levator muscle of the palatine arch, and shortly before the pseudobranchia is reached the pseudobranchial artery bifurcates into a short dorsal branch and a longer ventral branch. These vessels are analogous to the afferent branchial arteries of the branchial arches. Like them they give off the nutrient pseudobranchial arteries, from which the nutrient filament arteries arise for the pseudobranchial filaments (not shown in fig. 3.), and at regular intervals an *afferent pseudobranchial filament artery* (Pl. I, fig. 3; A.Ps.Fil.A.) is given off to the outer margin of the filament, which is the side that lies closest to the hyomandibular bone. As is the case in the branchial filament this artery exhausts itself in numerous afferent cross-vessels, which by dividing form the vessels from which the *pseudobranchial filament network* arises. These cross-vessels are much shorter than the corresponding branchial vessels and are about 80 μ apart, this being 20 μ more that the distance between 2 branchial filament cross-vessels. The longest septum of a pseudobranchial filament and the inclosed capillary network is much longer than the corresponding branchial septum, but the network itself is much coarser. In a like manner the capillary networks become collected into short cross-vessels on the inner side of the filament, which unite in forming the *efferent pseudobranchial filament vessels* (Pl. I, figs. 3 and 4; E.Ps.Fil.A). These vessels terminate in, and form a short dorsal, and a longer ventral artery, which lie immediately cephalad of the corresponding afferent vessels, and are analogous to an efferent branchial artery.[1] They unite in forming the important *ophthalmic*

[1] The pseudobranch is a hemibranch or half-gill. Although its capillary network is a trifle coarser than the network of a branchial filament and its afferent vessel comes from the external carotid artery, still it has much in common with a branchial filament. The septa containing the pseudobranchial capillaries are exposed to the same current of water that bathes the gills, and it is natural to

or *efferent pseudobranchial artery* (Pls. I, II and III, figs. 1, 5, 15, 19 and 20; Oph.A.), which supplies only the choroid coat of the eye.[2] This vessel pursues a dorso-cephalic course, passing along the outer posterior edge of the levator arcus palatini muscle to the parasphenoid bone; it then runs parallel to the parasphenoid for a short distance, and when the anterior surface of the dorsal parasphenoid process is reached, sends off a branch inward in front of this process to anastomose with the corresponding artery from the opposite side. Here the main stem bends dorsad nearly encircling the orbito-nasal artery, and passing between the inferior and internal rectus muscles in company with the ramus ciliaris brevis and the ophthalmic vein it follows along the posterior surface of the optic nerve, but before penetrating the sclerotic coat the artery makes a dorsal curve around the ciliaris brevis and the ophthalmic vein, and pierces the eyeball a little dorso-caudad of the optic nerve. After passing through the silver layer of the choroid it bifurcates in the vascular layer of the choroid into an *anterior choroid artery* (Pl. III, figs. 20 and 21; Chor.A.$_{(1)}$) and a shorter *posterior choroid artery* (Pl. III, figs. 20 and 21: Chor. A.$_{(2)}$). These 2 vessels have somewhat the shape of a horseshoe, having its curved end dorsad and its open end ventrad. Radiating from the outer surface of this horseshoe-shaped vessel are numerous short vessels, which soon break up into smaller vessels, and these in turn break up into minute parallel capillaries, forming the arterial retia mirabilia (Pl. III, figs. 19, 20 and 21; A.Ret.M.) of the so-called choroid gland or vaso-ganglion, which has already been accurately described by Jones (41), Müller (50), Stannius (74) and Emery (24). Distally these capillaries reunite, forming the *choroid arteries* proper (Pl. III, figs. 20 and 21; Chor.A.), which supply the choroid with arterial blood. A section through the choroid and retina (Pl. III, fig. 21) shows us that the choroid vessels are arranged in

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suppose that the arterial blood which passes through these filaments receives additional oxygen from the water.

[2] I have made several separate injections of the ophthalmic artery, cephalad, after it leaves the pseudobranchia to see if it had any connection with the other arteries, especially the orbitonasal artery with which it comes in such close contact; but no connection whatever was found.

2 layers; an outer layer of large arteries and veins, and an inner layer of capillaries. The capillary layer is separated from the retina only by the thin pigment layer of the choroid.

A little dorsad to the point of union of the hyoidean artery with the external carotid, the latter sends off, caudad, a smaller *posterior hyoidean artery* (Pl. I, fig. 1; P.Hyo.A.). Close to its point of origin this vessel gives off a dorsal branch, which runs in front of the preopercular and directly behind the ramus mandibularis VII, supplying the inner side of the deeper adductor mandibulæ muscle. Passing ventro-caudad through the same foramen as the hyoidean artery it runs parallel with it. In its course along the inner side of the preopercular it passes along the dorsal surface of the interhyal a little below the hyoidean vein; then curving around the ventral edge of the epihyal it comes to lie above the vein, finally terminating in several vessels to the hyohyoideus superior muscle in the region of the last branchiostegal ray.

(*b*) *Internal Carotid* or *Carotis Anterior Artery* (Pl. I, figs. 1 and 5; I.Car.A.). — This vessel after leaving the common carotid bends inward, passes ventrad across the jugular vein to penetrate the internal carotid foramen (a foramen formed by the dorsal process of the parasphenoid, the parasphenoid, and the prootic bones) into the eye-muscle canal. Here it divides into a cephalic and a horizontal trunk. The former is the orbito-nasal artery, and the latter unites in the median line, above the parasphenoid, with the corresponding trunk from the opposite side, the combined trunk being the encephalic or brain artery.

The *encephalic* or *brain artery* (Pls. I, II and III, figs. 1, 5, 15, 23 and 25: Enc.A.) proceeds dorsad between the external recti muscles and penetrating the floor of the brain case directly cephalad of the hypophysis, and exhausts itself in 4 branches, which are given off at right angles to one another. The cephalic one may be designated as the anterior cerebral artery, the lateral ones as the right and left posterior cerebral arteries, and the small posterior one as the infundibular artery.

Soon after leaving the main stem the *anterior cerebral artery* (Pl. III, figs. 23 and 25: A.Cer.A.) divides; the 2 branches running parallel for a short distance in a sort of zig-zag course along the ventral surface of the left optic nerve, and shortly before the olfactory lobes are reached they bear off laterad around the optic nerves, but, before leaving them, each vessel gives off a branch, which continues along the ventral surface of the nerve to the eye. This is the *optic* or *retina artery* (Pl. III, figs. 22, 23, and 25; Opt.A.), which gives off branches to the nerve and finally penetrates the eye-ball a little cephalad of the nerve. Once inside the retina it continues along the retina fissure (see fig. 22), giving off branches to either side and especially to a whitish gland-like body situated on the side of the fissure close to the falciform process. The main portion of the artery, however, breaks up on the falciform process, the campanula Halleri, and even extends over on the lens. It is also probable that the retina receives nourishment from the choroid arteries, which are separated from the retina only by the thin pigment layer of the choroid. The main anterior cerebral artery after curving around the optic nerve divides into an anterior and a posterior portion. Close to the point of bifurcation the anterior branch sends forward a small vessel, which runs along the ventral surface of the olfactory nerve, but the main trunk passes inward and anastomoses with its fellow in the median line. This point of union marks the source of 2 vessels, a smaller dorsal one designated as the most *anterior cranial cavity artery* (Pl. III, fig. 23; C.C.A.), coming up between the olfactory lobes to supply the adipose tissue in the anterior region of the cranial cavity and a larger caudal vessel, which runs in a median line between the optic nerves and the cerebral hemispheres, giving off several branches to the latter through the median fissure. The posterior branch of the anterior cerebral artery is a superficial vessel; it follows caudad along the ventro-lateral surface of the cerebrum, passing between it and the optic nerves, and giving off superficial branches to the ventral surface of the cerebrum and the anterior surface of the mesencephal. Sometimes the right, but more often the left artery continues dorsad with the epiphysis as the *second cranial cavity artery* (Pl. III, fig. 23; C.'C.'A.').

The *posterior cerebral arteries* (Pl. III, figs. 23 and 25; P.-Cer.A.) come off from the encephalic artery at right angles to the anterior cerebral artery; they run ventro-laterad across the optic nerves, the cerebral hemispheres, the III and IV nerves. Shortly after crossing the IV nerve each vessel makes a sharp curve at nearly right angles; then passing caudad between the IV nerve and the roots of the V and VII, parallel with, but inside of the corresponding vein, they give off several superficial branches to the mesencephal (optic lobes) and hypoaria (inferior lobes). The outer layer of the former contains a mass of blood vessels. Close to the posterior end of the hypoaria each posterior cerebral artery bends inward with the III nerve and the corresponding vein, between the mesencephal, hypoaria and crura cerebri, and when the saccus vasculosus is reached this vessel divides into an anterior and a posterior branch. The anterior branch unites with the corresponding vessel from the opposite side in the median line above the anterior part of the saccus vasculosus to form the *mesencephalic artery* (Pl. III, fig. 25; Me.A.), which passes cephalad a short distance in the crura; then turning dorsad, penetrates the floor of the mesencephal directly in front of the valvula cerebelli (volvula of other authors), and here sends out a lateral branch along the dorsal surface of each torus semicircularis. In like manner the posterior forks of the posterior cerebral arteries unite in the median line above the posterior end of the saccus vasculosus, and the vessel thus formed continues caudad along the ventral surface of the oblongata as the *myelonal* or *oblongata artery* (Pl. III, figs. 23 and 25; My.A.). Along its short course several branches are given off to the oblongata and one to the auditory region. The first vessel for the oblongata is given off near the source of the myelonal artery and passes up through the crura to the metacœle (IV ventricle), where it branches out caudad in the dorsal part of the crura. The second branch comes up through the ventral fissure of the oblongata in the neighborhood of the facialis lobe and breaks up similarly to the first branch. The third branch, which is much larger, is the *auditory artery* (Pl. III, figs. 23, 23*a*, 24 and 25; Aud.A.). Its course is obliquely laterad across the oblongata, but before coming out from under the roots of the VII nerve, sends up a dorsal branch, the *third cranial cavity artery* (Pl. III, figs. 23

and 23*a*: C.″C.″A.″), which passes between the ventral lateralis and the motor roots of the VII nerve to the roof of the skull, supplying the adipose tissue surrounding the brain and the semicircular canals. Emerging from beneath the motor root of the VII nerve, the auditory artery divides into an anterior and a posterior auditory artery. The *anterior auditory artery* (Pl. III, figs. 23*a* and 25; A.Aud.A.) follows along the anterior surface of the ramulus acusticus ampullæ anterioris; passing beneath the anterior ampulla to which it gives off a branch, it continues on to the external ampulla and its semicircular canal. The *posterior auditory artery* (Pl. III, figs. 23, 23*a* and 25; P.Aud.A.), which at first passes caudad under the ramulus acusticus ampullæ anterioris and the ramulus acusticus sacculi, comes up through the center of the latter and passes along in front of the ramulus acusticus ampullæ posterioris, to supply the posterior ampulla, its semicircular canal, and the utriculus. The myelonal artery terminates in 2 forks on the ventral surface of the myel, in the region of the first spinal nerves. These branches usually anastomose with a branch of the first neural or vertebral arteries, which having their origin from the subclavians make them analogous to the anastomosis of the basilar and vertebral arteries of mammals, of which a more detailed description will be given under the subclavian arteries. At the point where the posterior cerebral artery bends to penetrate the mesencephalon it gives off, caudad, the *cerebellum artery* (Pl. III, figs. 23 and 24; Cer.A.). This vessel continues parallel, but above the IV nerve, ventrad to the optic lobes, and laterad to the crus. In its caudal course it gradually rises higher on the crus, until in the region of the posterior end of the optic lobes it gets to lie between the optic lobes and the valvula cerebelli. A little behind the origin of the IV nerve and the posterior end of the optic lobes this vessel penetrates the dorso-lateral wall of the valvula cerebelli at the point where the molecular layer of the valvula unites with the corresponding layer of the cerebellum. Its course is then caudad a little to one side of the median line, gradually exhausting itself in the granular layer of the cerebellum.

The fourth and smallest vessel to be given off from the encephalic artery is the *infundibular artery* (Pl. III, fig. 25 : Inf.-A.). This vessel, which is given off caudad to the hypophysis and infundibulum, sometimes arises from either of the posterior cerebral arteries close to their origin from the encephalic artery.

Orbito-nasal Arteries (Pls. I, II and III, figs. 1, 5, 13, 17 and 18 ; O.N.A.). — These vessels which are the cephalic branches of the internal carotid arteries, pass forward along the dorso-lateral surface of the parasphenoid. While still within the eye-muscle canal each orbito-nasal artery runs below the recti muscles, giving off several small branches to the superior, inferior, and internal recti muscles. Shortly after reaching the orbit, what I have designated as the *rectus artery* (Pl. II, fig. 13 ; Rec.A.) arises between the internal and the inferior recti muscles, giving off at first a small branch to the outer surface of the internal rectus muscle ; then dividing, one branch continues caudad between the external and internal recti muscles ; while the other branch curves laterad a short distance and in turn bifurcates, one branch going dorsad to the superior rectus muscle, and the other to the inferior rectus muscle. The main orbito-nasal trunk, continuing cephalad, passes behind the internal rectus muscle to which it sends several vessels ; and in the anterior part of the orbit passes between, but laterad to the oblique muscles, giving off a dorsal branch to the superior oblique muscle, and in the specimen from which fig. 13 was drawn, 2 ventral branches for the inferior oblique muscle. As has already been mentioned, the blood supply for the external rectus muscle comes largely from the iris artery, which is a branch of the external carotid artery. Together with the orbito-nasal vein and the olfactory nerve, the orbito-nasal artery passes out of the orbit through the olfactory foramen in the prefrontal bone. In passing through this foramen and cephalad of it, the vein lies mesad of the nerve, and the artery lies ventrad to both vein and nerve. Soon after leaving the orbit the orbito-nasal artery gives off at least 2 dorso-cephalic vessels, the *nasal sac arteries* (Pl. III, figs. 17 and 18 : N.S.A.$_{(1)}$). These small vessels at first pass behind and above the olfactory nerve to supply the dorsal radial filaments of the nasal sac. They penetrate the base of the filaments with branches of the olfactory nerve, and running through the inner connective tissue layer send off branches into the secondary or branching filaments. The main orbito-nasal trunk after passing behind the nasal sac with the corresponding vein and the olfactory nerve divides into a cephalic and a ventral branch. The smaller cephalic branch, crossing behind the orbito-nasal vein, proceeds above it, and becomes the *maxilla artery* (Pls. I and III, figs. 1, 17 and 18; Max.A.$_{(1)}$). This artery in turn also breaks up into 2 vessels; a dorsal one, which penetrates the premaxilla; and a ventral one, which runs along the posterior surface of the premaxilla. The larger ventral branch is the *posterior maxilla artery* (Pls. I and III, figs. 1, 17 and 18; Max.A.$_{(2)}$); at the ventral edge of the nasal sac it sends a branch inward to the palatine arch; and directly below this branch at least 2 *ventral nasal sac arteries* (Pl. III, fig. 17; N.S.A.$_{(2)}$) are given off dorsad, which supply the ventral filaments in a like manner to dorsal nasal sac arteries. Then anastomosing with the much smaller facialis-maxillaris artery it runs along and breaks up on the outer surface of the adductor mandibulæ muscle, immediately behind the maxilla.

(*c*) *Summary of the Carotids.* — Parker has well said (60, P. 653), that: "The application of the name 'carotid' to the cephalic arteries of fishes must of course be taken to imply nothing more than a general correspondence with the similarly named vessels in the higher Vertebrata." For example, his anterior carotid (internal carotid) in *Mustelus* (60, fig. 6), and the similar artery in *Hydrolagus*, Chimæra (Pl. III, fig. 26; I.Car.A.), are almost analogous to the ophthalmic artery of *Ophiodon* (Pl. I, figs. 1 and 5; Oph.A) provided that it anastomosed with the orbito-nasal artery with which it comes in such close contact. In the same connection, Parker proposes to substitute the names anterior and posterior carotids for the internal and external carotids. This substitution may seem advisable in the Selachians, where the carotids at first occupy a distinctly anterior and posterior position; but in the case of the Teleosts that I have examined the vessel which has been designated as the internal carotid has a distinctly profundus course, and the external carotid a superficial one. Even though the cephalic portion of the internal carotid crosses the tract of the external carotid and a branch of one anastomoses with a branch of the other, still, in the main, the internal carotid supplies the region of the internal carotids of the Mammalia. It certainly extends no farther cephalad than the exteral carotids. For these reasons, in *Ophiodon*, it seems advisable to retain the names internal and external.

4. *Opercular and Dorsal Branchial Muscle Arteries.*

These vessels are 2 very constant arteries, which arise from the dorsal part of the second efferent branchial artery.

Of the 2, the *opercular artery* (Pl. I, fig. 1; Op.A.) is the most dorsal and cephalic vessel. It arises from the anterior surface of the second efferent branchial artery near its point of union with the first efferent branchial artery; its course is first cephalad for a short distance, passing over the second obliquus dorsalis muscle, to which it gives a branch; then curving dorsad, sends off a cephalic branch, which supplies the first internal branchial levator muscle (Levatores arcuum branchialium interni of Vetter) and the first obliquus dorsalis muscle; and a little farther up, a third artery is given off to the 4 outer branchial levator muscles (Levatores arcuum branchialium externi of Vetter). Then continuing dorsad, laterad to the first efferent branchial artery and jugular vein, it sends off a caudal branch to the levator operculi muscle of Vetter, and when the level of the opercular is reached, terminates by running ventrad along the inner surface of this bone.

The vessel, which is designated as the *dorsal branchial muscle artery* (Pl. I, fig. 1; Br.M.A.), but which supplies fewer branchial muscles than the one designated as the opercular artery, arises from the posterior surface of the second efferent branchial artery directly below the opercular artery. Its course is caudad, passing behind the second internal branchial levator muscle, and over the third and fourth obliqui dorsales muscles, it sends off a branch to each. Then after crossing over the fourth efferent branchial artery it curves ventrad, supplying the occipito-clavicularis muscle, the pharynx, and the dorsal part of the pharyngo-clavicularis internus muscle.

5. *Subclavian Arteries.*

The *subclavian arteries* (Pls. I and II, figs. 1, 5, 14 and 16; Sub.A.), usually,[1] have their origin in a single trunk from the *common chamber* (fig. 5, C.C.). This *common subclavian trunk* (Pl. I, fig. 5) arises above and between the dorsal aorta and the cœliaco-mesenteric artery. For a short distance it runs parallel to the aorta and the cœliaco-mesenteric artery, and then branches at nearly right angles; the right subclavian passing obliquely above the cœliaco-mesenteric artery, the right dorsal branchial retractor muscle, and the right head kidney to the right pectoral fin; while the left subclavian passes between the aorta and the cœliaco-mesenteric artery, above the left dorsal branchial retractor muscle and left head kidney to the left pectoral fin.

After crossing the head kidney the course of each subclavian is ventrad, passing with the combined trunk of the first and second spinal nerves across the outer surface of the head kidney and cardinal vein to the inner surface of the pectoral fin. In the region of the dorso-lateral edge of the head kidney the subclavian gives off the *first neural artery* (Pls. I and II, figs. 1 and 16; Neu.A.$_{(1)}$), which is somewhat analogous to the vertebral artery in mammals. This vessel runs obliquely dorsad in front of the combined trunk of the first and second spinal nerves, and then passes over the second and first epibranchial arteries, but behind the thymus gland. When the atlas is reached it gives off the *first spinal* or *myclon artery* (Pl. II, fig. 16; Sp.′A.′), which enters a foramen in the exoccipital and usually anastomoses with the myelonal artery. The main stem, however, continues dorsad, terminating in a cephalic, and a dorsal branch. The cephalic branch supplies the trapezius muscle and sends a branch ventrad, which probably supplies the thymus gland. This small vessel I have been able to trace to the thymus, but never have seen it penetrate the gland. Strange to say the arterial supply for the thymus is more difficult to trace than the venous system. The dorsal branch of the first neural artery is destined to supply the superficial, the levator, and the depressor muscles of the first dorsal

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[1] For exception see page 45.

spine; and in the specimen from which fig. 16 was drawn, the levator muscle of the second dorsal spine, as well as sending up a branch behind the first dorsal spine.

After giving off the first neural artery the subclavian might be designated as the brachial artery as in mammals, but it seems hardly advisable to press such homologies. Emerging from the head kidney the subclavian passes ventrad along the inner anterior surface of the pectoral superficial adductor muscle; and when the pectoral profundus adductor muscle is reached, a branch is given off to the superficial muscle; then bifurcating, forms what I have designated as the external and internal subclavians.[1] The *internal subclavian artery* (Pl. II, fig. 14; I.Sub.A.) for a short distance continues along the inner cephalic edge of the superficial adductor muscle; then divides into a *superficial internal subclavian artery* (Pl. II, fig. 14; I.Sub.A.$_{(1)}$), which after giving off a few branches to the superficial adductor muscle continues obliquely ventrad along the inner surface of the profundus adductor muscle; and a *profundus internal subclavian artery* (Pl. II, fig. 14; I.Sub.A.$_{(2)}$), which immediately penetrates both superficial and profundus adductor muscles and runs obliquely ventrad between the profundus muscle and the scapula, giving off several branches to the former. In the neighborhood of the most dorsal pectoral ray this vessel divides into a brachial ossicle artery and a pectoral fin artery. The brachial ossicle artery crosses these bones in its ventral course just back of the pectoral rays, and exhausts itself by giving off vessels to the distal part of the profundus muscle and by sending off branches between the ossicles to the profundus muscle on the outside of the shoulder-girdle. While the pectoral fin artery penetrates the basal canal (see note, page 50) between the first, or most dorsal, and the second rays, and continuing ventrad in this canal anastomoses with the hypobranchial artery. Throughout its entire course it gives off a branch to the central canal of each ray, which soon divides, one branch continuing along the dorsal side of the cavity and the other along the ventral side. The *external subclavian artery* (Pl. II, fig. 14; E.Sub.A.) immediately passes

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[1] Perhaps external and internal pectoral arteries would be better names.

through the scapula foramen with the external subclavian vein and a branch of the first and second spinal nerves, and then runs obliquely ventrad between the superficial and profundus abductor muscles, giving off several branches to each.

6. *Cœliaco-Mesenteric Artery.*

The *cœliaco-mesenteric artery* (Pl. I, figs. 1 and 5; Cœ-Mes.A.), which is destined to supply the entire viscera with the exception of the kidney, urinary-bladder, and reproductive organs, is in itself a rather short vessel. With the subclavian it has its source in the *common chamber* (Pl. I, fig. 5; C.C.) beneath and to the right of the aorta and subclavians. It pursues a ventro-caudal course, and passing between the inner side of the right fork of the kidney and the right dorsal branchial retractor muscle enters the thoracic cavity, where it soon divides into the cœliac and mesenteric trunks.

(*a*) *Cœliac Artery* (Pl. I, figs. 1, 6 and 11; Cœ.A.). — This large vessel for a short distance, runs parallel, but cephalad to the mesenteric artery, then curving around under the stomach, supplies the liver, ventral part of the stomach, pyloric cæca, and a part of the posterior end of the intestine.

The first branch to be given off from the cœliac is the *left hepatic artery* (Pl. I, figs. 6 and 11; L.Hep.A.). It leaves the cœliac under the stomach and breaks up into as many branches as there are terminal branches of the left portal vein. These branches are somewhat irregular, but the first and most cephalic one accompanies terminal branch (*a*) of the left portal vein. Usually this branch is the source of the *posterior gall-bladder artery* (Pl. I, fig. 11; P.G.Bl.A.), which runs along the dorsal surface of the gall-bladder and anastomoses with the anterior gall-bladder artery, which is a branch of the right hepatic artery (a branch of the mesenteric artery). Both gall-bladder arteries break up into a minute capillary system on the surface of the gall-bladder. A minor posterior gall-bladder artery is often given off to the ventral surface of the gall-bladder (see fig. 11). The second branch of the left hepatic artery accompanies terminal branch (*b*) of the left portal vein and the remaining branches follow terminal branches (*c*), (*d*) and (*e*). Ordinarily 1 or 2 branches from the last mentioned arteries follow along in the gastro-hepatic omentum to supply the ventral portion of the stomach. All of the branches of the left hepatic artery follow their corresponding venous trunks to their terminal endings in the substance of the liver. The left hepatic artery furnishes the principal arterial supply for the liver, but in some specimens an additional *posterior* or *minor left hepatic artery* (Pl. I, fig. 11 ; L.Hep.A.$_{(1)}$) arises from the cœliac a little farther caudad than the main left hepatic artery and anastomoses with the posterior branches of the left hepatic vessel. Beside the left hepatic vessels there is also the right hepatic artery for the small right lobe of the liver, which will be described further on under the mesenteric artery.

Continuing caudad, parallel, but to the right of the left portal vein, the cœliac artery divides directly in front of the pylorus into a right and left pyloric cæca artery. One of these forks (usually the right) is always considerably longer than the other. The *right pyloric cæca artery*, Pl. I, figs. 1 and 6 ; R.Cæ.A.) passes at least two-thirds around the pylorus, inside of the pyloric cæca vein a little above the cæca, and in its course gives off at least 3 branches to the cæca. Within the cæca the larger vessels run in the muscular coats and break up into a capillary network in the connective tissue layer of the crypts as in the intestine. One branch of the right pyloric cæca artery is sent off to the pylorus and 2 rather large posterior gastric arteries are given off to the posterior or cardiac portion of the stomach. From the *right posterior gastric artery* (fig. 1 ; R.P.Gas.A.) one or more branches run along in the peritoneal fold over the cæca to anastomose with the intestinal branch of the mesenteric artery. The left pyloric cæca artery, which is usually much smaller than the right, pursues a similar course on the left side of the pylorus, giving off 2 or 3 branches to the cæca and one to the pylorus. When this is the smaller of the 2 cæca arteries, no branches are given off from it to the posterior end of the stomach, however, only in about one case in 10 is the left pyloric cæca artery larger than the right.

Quite an important vessel arises from the right side of the cœliac artery shortly before it separates to form the pyloric cæca arteries, or sometimes it may arise from the right pyloric cæca artery; it is the vessel designated as *intestinal artery*$_{(2)}$ (Pl. I, figs. 1, 6 and 11; Int.A.$_{(2)}$), which strikes the intestine about mid-way between the pylorus and the rectum. For a short distance it runs along, inclosed in adipose tissue, just dorsad of the intestine, and crossing over to the ventral side of the intestine, exchanges places with intestinal artery$_{(1)}$. This vessel is distinctly a posterior intestinal artery and usually extends to the rectum. Throughout its entire course it sends off branches to the muscular walls of the intestine, which break up into a capillary network in the connective tissue layer of the crypts. In the region of the liver several small branches from the cœliac are given off to the anterior part of the intestine.

(*b*) *Mesenteric Artery* (Pl. I, fig. 1; Mes.A.). — This vessel is destined to supply the spleen, the greater part of the stomach, and intestine. Soon after leaving the cœliaco-mesenteric trunk the mesenteric artery gives off the *left gastric artery* (Pl. I, figs. 1 and 6; L.Gas.A.) to the left and ventral side of the stomach. This vessel, which lies above the corresponding vein and left gastric ramus of the vagus nerve, crosses the stomach at right angles, then passing along the left side of the stomach, gives off branches to either side, which soon penetrate the muscular walls and break up into a capillary network in the connective tissue layer of the crypts. The main mesenteric trunk after following the stomach for a short distance bifurcates into the right gastric, and intestinal artery$_{(1)}$. The *right gastric artery* (fig. 1; R.Gas.A.), which is considerably larger than the left, continues between the right gastric ramus of the vagus nerve and the right gastric vein to the posterior or cardiac portion of the stomach, giving off branches from either side to the muscular walls of the stomach. Close to its origin it sends off a branch to the right (see fig. 1), which crosses the cœliac artery and the right portal vein to a gland-like body (G. fig. 1) situated at the junction of the right gastric and the intestinal veins (in structure this gland is very much like the suprarenal bodies). The *Intestinal artery*$^{(1)}$ (Pl. I, figs. 1 and 6; Int.A.$_{(1)}$) pursues a general caudal direction. Close to its origin this vessel gives off the *right hepatic artery* (Pl. I, fig. 11; R.Hep.-A.), which supplies the smaller right lobe of the liver. This branch runs along by the side of the right portal vein and midway between its source and the right lobe of the liver sends off the *anterior gall-bladder artery* (Pl. I, fig. 11; A.G.Bl.A.)., which breaks up on the anterior surface of the gall-bladder, and as has already been mentioned under the head of the posterior gall-bladder artery, the 2 gall-bladder arteries anastomose on the surface of the bladder. A little farther caudad, the *anterior intestinal* or *duodenum artery* (fig. 1; A.Int.A.), is given off from the intestinal artery to the anterior loop of the intestine. The main intestinal trunk then sends off the rather large *splenic artery* (Pl. I, figs. 1 and 6; Spl.A.), which penetrates the anterior surface of the spleen, together with, but dorsad of the splenic vein. Once inside the spleen, it runs entirely through the organ, branching out in the shape of a fan. The intestinal artery, curving around the dorsal surface of the spleen runs along in adipose tissue, parallel with, but closer to the intestine than the corresponding intestinal vein. This artery varies greatly in length. Usually, however, it continues to the rectum, receiving anastomotic branches from the right posterior gastric artery, and curving around to the opposite or dorsal side of the intestine, anastomoses with the *posterior mesenteric artery* (fig. 1; P.Mes.A.). In several specimens, however, the intestinal artery did not continue much farther caudad than the spleen, and the posterior part of the intestine usually supplied by this vessel received its supply from the right posterior gastric artery and the posterior mesenteric artery. As in the stomach and cæca, the larger vessels run in the longitudinal and circular muscular coats and break up into a network of capillaries in the connective tissue coat.

(*c*) *Comparisons with Other Genera of the Suborder.*— In different genera, it is within the viscera where most of the variation in the blood vessels occur. This is perhaps in a large measure due to the variation in the shape and location of the various organs and to the presence or absence of certain of them. Of the 3 fishes figured in plate IV, probably the arterial supply for the viscera of *Scorpænichthys* is most like *Ophiodon*, and *Sebastodes* most like the ordinary Acanthopterygian fishes.

The origin of the cœliaco-mesenteric trunk is the same for all 4 genera studied, but as regards the branching of the cœliac and especially the mesenteric, there is considerable variation.

Cœliac Artery. — In *Hexagrammos* the cœliac branches off from the cœliaco-mesenteric trunk much further caudad than is the case with the other 3 genera; in fact, the cœliac and the left gastric are given off together. In all 4 genera the cœliac terminates by dividing into the 2 pyloric cæca arteries, but in *Ophiodon* only does a pyloric cæca artery supply the posterior part of the stomach. In *Sebastodes* the *left hepatic arteries* (Pl. IV, fig. 32: L.Hep.A.) arise in a similar manner to the corresponding vessels of *Ophiodon*, except that the posterior left hepatic artery is much larger than in *Ophiodon*; while in *Scorpænichthys* and *Hexagrammos*, strange to say, the left hepatic arises from the right gastric, but in *Hexagrammos* it comes into such close contact with the cœliac that at first one might be led to believe it arose from the cœliac or at least anastomosed with it. In *Hexagrammos* only does the intestinal artery$_{(2)}$ arise from the cœliac as in *Ophiodon*; in *Scorpænichthys* and *Sebastodes* it is a branch from intestinal artery$_{(1)}$.

Mesenteric Artery. — The right and left gastric arteries respectively are essentially the same in all 4 genera. However, since there are so many variations in the branching of the right gastric, the distribution of intestinal artery$_{(1)}$, and the additional air-bladder and anterior spermatic arteries in *Sebastodes*, it seems advisable to describe in detail the distribution of the mesenteric artery for each of the above genera.

Mesenteric Artery in Scorpænichthys (Pl. IV, fig. 29; a fork of Cœ. Mes.A.). — After giving off the left gastric artery, the mesenteric artery separates into the *right gastric artery* (fig. 29, R.Gas.A.) and the intestinal artery$_{(1)}$(fig. 29; Int.A.$_{(1)}$). The former gives off the *left hepatic artery* (figs. 29 and 30: L.-Hep.A.) and the latter follows along the stomach for a short distance, giving off a small branch to a small gland-like body, marked *g*, and the *splenic artery* (Pl. IV, fig. 29; Spl.A.), but before entering the spleen this vessel sends off a *posterior gas-*

tric artery (Pl. IV, fig. 29; P.Gas.A.), which supplies the ventral posterior or cardiac portion of the stomach. The main intestinal trunk crosses the cæca and after passing under the first arm of the ileum sends off *intestinal artery*$_{(2)}$ (Pl. IV, fig. 29; Int A.$_2$), which supplies the posterior part of the intestine; while the main intestinal trunk continues caudad, supplying both arms of the ileum. Except from the different points of origin, the *left hepatic artery* (Pl. IV, figs. 29 and 30; L.Hep.A.) coming from the right gastric artery, and the *right hepatic artery* (Pl. IV, figs. 29 and 30; R.Hep.A.) from the left gastric artery, the peripheral distribution of the 2 hepatic arteries is practically the same as in *Ophiodon*. Perhaps it should be mentioned that there is but one left hepatic artery in *Scorpænichthys*.

Mesenteric Artery in Hexagrammos (Pl. IV, fig. 27; Mes.-A.). — As has already been stated, the *left gastric artery* (Pl. IV, fig. 27; L.Gas.A.), which is much shorter than in the other 3 genera, is given off almost directly opposite the cœliac artery. This would make it appear as though the cœliaco-mesenteric trunk separated into 3 branches, namely, the cœliac, mesenteric and left gastric arteries. The mesenteric artery runs along the stomach for a short distance and divides into the characteristic right gastric and intestinal arteries. As in *Ophiodon* the *right gastric artery* (Pl. IV, fig. 27; R.Gas.A.) follows along the right and upper side of the stomach, but it has, however, exchanged positions with the right gastric vein. In this respect it also differs from *Scorpænichthys* and *Sebastodes*. Close to its source it gives off the left *hepatic artery* (Pl. IV, figs. 27 and 28; L.Hep.A.), which comes into very close contact with the cœliac artery and breaks up into 3 branches, which penetrate the liver with terminal branches *a*, *b*, and *c* of the left portal vein. The branch following terminal branch *a* anastomoses with the right hepatic artery in a similar manner to the anastomosing of this branch of the left portal with the right portal vein. As in *Scorpænichthys* there is but one left hepatic artery. The *Intestinal artery*$_{(1)}$ (Pl. IV, fig. 27; Int.A.$_{(1)}$) soon after leaving the mesenteric artery sends off the *right hepatic artery* (Pl. IV, fig. 27; R.Hep.A.), which at first runs along the surface of the gall-bladder as the gall-bladder artery, and penetrating the liver with the right portal vein, anastomoses with the most anterior branch of the left hepatic artery. By this anastomosis the conditions are somewhat analogous to *Ophiodon;* where the posterior gall-bladder artery, which arises from the most anterior branch of the left hepatic artery, anastomoses on the surface of the gall-bladder with the anterior gall-bladder artery, which is a branch from the right hepatic artery. The intestinal artery$_{(1)}$ then crosses above the anterior or duodenum portion of the intestine and intestinal vein$_{(2)}$, gives off several branches to the intestine and then continuing caudad with the intestinal vein$_{(1)}$, between the arms of the iliac loop, extends past the loop to supply the rectum. When near the end of the loop the *splenic artery* (Pl. IV, fig. 27; Spl.A.) is given off to the spleen, which, strange to say, is located on the posterior end of the intestine close to the rectum. However, before entering the spleen, the splenic artery sends off a branch to the posterior end of the intestine.

Mesenteric Artery in Sebastodes (Pl. IV, fig. 31; Mes. A.). — In this genus, which is supposed to be less specialized than the above genera, several new features are introduced, among them, a vessel for the air-bladder and 2 for the reproductive organs. After giving off the *left gastric artery* (Pl. IV, fig. 31; L.Gas.A.), which is the principal artery for the stomach, the mesenteric artery bifurcates into its 2 characteristic divisions, namely, the right gastric, and intestinal artery$_{(1)}$. The *right gastric artery* (fig. 31; R.Gas.A.) in *Sebastodes* is much shorter than in the other 3 genera and gives off several important trunks. The first important branch is the *right anterior spermatic artery* (Pl. IV, fig. 31; R.Sper.A.). Together with the corresponding vein this vessel passes caudad under the air-bladder vessels to supply the right ovary or testis with a large part of its arterial blood, and anastomoses above with the spermatic artery proper (fig. 31; Sper.A.). The second vessel to be given off from the right gastric is the small *right hepatic artery* (Pl. IV, fig. 31; R.Hep.A.). This vessel penetrates the right lobe of the liver with the right portal vein, and often sends off a branch to a gland-like body situated near the right portal vein. Usually the right hepatic artery gives off the *anterior* *gall-bladder artery* (Pl. IV, fig. 34; A.G.Bl.A.). In case such a branch is given off it usually supplies the above mentioned gland (see fig. 34; G.) The third branch of the right gastric is the *air-bladder retia mirabilia* or *anterior air-bladder artery* (Pl. IV, fig. 31; A.Bl.A.); it crosses above intestinal artery$_{(1)}$ and the right anterior spermatic vessels, just in front of the right mesenteric and the anterior air-bladder veins. Penetrating the thick ventral muscular walls of the air-bladder it breaks up internally into small branches, which in turn break up into minute parallel arterial capillaries, that become continuous distad with parallel venous capillaries, and which are afterward collected into small veins that empty into the air-bladder retia mirabilia vein. This sort of a horseshoe-shaped mass of capillaries on the floor of the air-bladder is known as the retia mirabilia or vaso-ganglion of the air-bladder; it is a vaso-ganglion of the bipolar type. This broad expanse of capillaries affords a good opportunity for the exchange of gases from the blood to the bladder and conversely. The fourth and last branch to be given off from the right gastric artery is the *left anterior spermatic artery* (Pl. IV, fig. 31; L.Sper.A.). This vessel pursues a similar course to the right anterior spermatic artery, following parallel with the corresponding vein it helps supply the left ovary or testis and anastomoses posteriorly with the spermatic artery proper. *Intestinal artery*$_{(1)}$ (Pl. IV, fig. 31; Int.A.$_1$) pursues a general caudal course, passing under or rather to the right of all the above mentioned arteries. When in the neighborhood of the spleen it divides; the posterior fork, which is designated as the continuation of the main intestinal artery$_{(1)}$, passes caudad to supply the posterior end of the intestine; while the anterior fork soon divides into the splenic artery and what I have designated as intestinal artery$_{(2)}$. *Intestinal artery*$_{(2)}$ (Pl. IV, fig. 31; Int.A.$_2$) is so named because it runs parallel with a vein, which has the same terminus as intestinal vein$_{(2)}$ of *Ophiodon*, but it is hardly probable that this artery is homologous with intestinal artery$_{(2)}$ of *Ophiodon*. This artery separates into an anterior branch, which supplies the anterior part of the intestine or duodenum and a posterior branch, which supplies the iliac part of the intestine. In some specimens where there was no anterior gall-bladder artery, as is shown in fig. 33, there is a *posterior gall-bladder artery* (fig. 33; P.G.Bl.A.) arising from the intestinal artery$_{(2}$, which in addition to supplying the gall-bladder is continued caudad to supply a portion of the ileum. The *splenic artery* (Pl. IV, fig. 31: Spl.A.) penetrates the spleen with the splenic vein, but before entering it, gives off a *posterior gastric artery* (Pl. IV, fig. 31; P.Gas.A.), which passes beneath the spleen to the ventro-posterior end of the stomach; and like the posterior gastric artery of *Ophiodon*, which, however, has a different origin, coming from the right pyloric cæca artery, it sends off a branch to the posterior portion of the intestine.

7. *Dorsal Aorta.*

This vessel (Pl. I, figs. 1, 5, and 10 D.Ao.), which is the largest artery in a fish, arises as the most dorsal trunk from the *common chamber* (Pl. I, fig. 5; C.C.) and continues caudad in a median line directly below the vertebral column to the last caudal vertebra. At first the dorsal aorta runs between the 2 anterior lobes of the kidney, above and between the dorsal branchial retractor muscles, and when the posterior unpaired part of the kidney is reached, runs along in its dorsal groove. After leaving the kidney and the body cavity, the aorta is known as the *caudal artery* (Pl. I, figs. 1, 7, 8, 9 and 10; Cau.A.). It penetrates the hæmal canal of the first caudal vertebra with the caudal vein and continues in the hæmal canal above the vein until the last caudal vertebra is reached, where at about the middle of the last centrum it separates into a right and a left caudal artery. The *left caudal artery* (Pl. I, fig. 8; L.Cau.A.) is much the shorter; it sends a branch upward in front of the urostyle, which supplies both profundus and superficial muscles. The much larger *right caudal artery* (Pl. I, figs. 1 and 8; R.Cau.A.) following along the outer margin of the last centrum and after giving off a branch in front of the urostyle similar to the left caudal artery, continues caudad in a median line between the 2 hypural bones, parallel with the longitudinal hæmal lymphatic vessel, giving off branches from both sides to the profundus muscle of the caudal fin. When the caudal fin is reached this artery bifurcates into a dorsal and a ventral vessel, which run dorsad or ventrad in the basal canal of the caudal rays, directly in front of the corresponding lymphatic and venous vessels. The central canal of each ray receives a branch, which at first runs in the center of the cavity and then divides, the 2 forks continuing caudad along the dorsal and ventral sides of the canal.

Throughout its entire course the dorsal aorta gives off branches to the great lateral muscles, the spinal cord, and the rays of the unpaired fins; beside supplying the kidney, reproductive organs and the rectum.

(*a*) *Arteries Supplying the Great Lateral Muscle, Cord, etc.*—Perhaps the most typical place first to take up these vessels is in the region of the caudal vertebræ. In fig. 1 such a region is shown just posterior to the kidney. The common arrangement consists of a dorsal or neural artery and a ventral or hæmal artery, which usually supply the region covered by 2 myotomes; sometimes, however, one of these arteries may supply 3 or even 4 myotomes.

The dorsal or *neural arteries* (Pl. I, fig. 1; Neu.A.) in this region arise from the dorsal side of the caudal artery. Emerging from the anterior surface of the hæmal arch each neural artery curves around the anterior end of either the right or left side of the centrum. Here a branch, the *median lateral artery* (fig. 1; M.Lat.A.) is given off to the great lateral muscle. A second branch, the *spinal* or *myelon artery*, penetrates the spinal foramen. The neural artery then curves around in front of the neural spine and continues dorsad between the spine and the neural lymphatic vessel. Near the end of the spine the *dorsal lateral artery* (fig. 1; D.Lat.A.) is given off to the great lateral muscle. Then passing cephalad the neural artery supplies the levator and depressor muscles of this and the preceding dorsal rays, as well as supplying the superficial muscles and sending up a branch behind this and the preceding dorsal rays. This description will hold for all the neural arteries from the head to the tail, except that the most cephalic one arises from a different source (see under Subclavian artery), and the second and third neural arteries (fig. 5 : Neu.A.$_{2 \text{ and } 3}$) supply the dorsal branchial retractor muscles and the anterior forks of the kidney in addition to the musculature already described.

Hæmal Arteries (fig. 1 ; Hæ.A.).—These vessels arise from the ventral side of the caudal artery, a little behind the corresponding neural arteries, and crossing over the caudal vein run ventrad between the hæmal spines and the hæmal lymphatic vessels. Near the end of the spines they give off the *ventral lateral arteries* (fig. 1 ; V.Lat.A.) for the great lateral muscle, then curving cephalad, break up among the superficial and profundus anal ray muscles in like manner to the neural arteries in the dorsal fin musculature. The homologous intercostal arteries of the visceral body wall have their origin in a common vessel, which supplies also the kidney and often the reproductive organs.

(*b*) *Renal and Spermatic Arteries.*—As has just been stated, the renal and spermatic arteries as well as the intercostals often have their source in one and the same artery, which is probably homologous with the hæmal arteries of the caudal region. For convenience we will speak of these common trunks in the region of the anterior part of the kidney as the intercostal arteries and in the region of the posterior part of the kidney, where the main branch goes to the reproductive organs, as the spermatic arteries.

Intercostal Arteries (fig. 1 ; Intc.A.).—These vessels arise from the ventral side of the aorta, in the region of each alternate vertebra, and passing across the lateral surface of either side of the kidney, they give off several *renal arteries* (fig. 1 ; Ren. A.) for the kidney ; but the main trunks or intercostal arteries proper continue ventrad between 2 myotomes and anastomose with branches from the ventral artery, the so-called ventral intercostal arteries.

Spermatic Arteries (Pl. I, figs. 1 and 10 ; Sper.A.).—In both male and female there are at least 3 spermatic arteries, which always cross the left side of the kidney, giving off several renal arteries and one intercostal artery before leaving the kidney for the reproductive organs. These arteries increase in size as these organs increase in size toward the breeding season, which is in January at Monterey Bay. In the female these vessels branch before reaching the ovaries and these branches spread out over the outer and inner surfaces of the ovaries; while in the male these branches penetrate directly into the testes. No common spermatic artery is formed in either male or female by the anastomosis of these branches, to pass between and parallel with the reproductive organs, as is the case with the veins. The *anterior spermatic artery* (Pl. I, figs. 1 and 10; Sper.A.$_1$) arises from the ventral surface of the aorta and passing obliquely ventrad across the left side of the kidney, gives off 1 or 2 renal arteries for the kidney and an intercostal artery, which passes ventrad between the 2 adjacent myotomes; the main spermatic trunk also continues ventrad to break up on the anterior surface of the ovaries or to penetrate the testes. The *second spermatic artery* (Pl. I, figs. 1 and 10; Sper.A.$_2$) is given off from the aorta, about the distance of 2 vertebræ from the first spermatic artery, and in like manner sends off renal and intercostal arteries for the kidney and body-wall; while the main trunk supplies the middle portion of the ovaries or testes. The *third* or *posterior spermatic artery* (Pl. I, figs. 1 and 10; Sper.A.$_3$) is much the largest; in addition to supplying the ordinary renal and intercostal arteries, it gives off from 1 to 3 *suprarenal arteries* (Pl. I, figs. 1 and 10; Sr.A.) for that gland. In fig. 1 the third spermatic artery passed in front of the gland and only one artery was observed to enter the gland; while in fig. 10 the main artery passed behind the gland and at least 3 arteries were seen to penetrate it. In the specimen from which fig. 1 was drawn the *posterior mesenteric artery* (fig. 1; P.Mes.A.) arises from the last spermatic artery, passing behind the posterior mesenteric vein, it continues ventrad with it between the ovaries to supply the rectum and anastomoses with intestinal artery$_{(1)}$; while in the specimen from which fig. 10 was drawn the posterior mesenteric artery was given off much further dorsad and at first entered the kidney as a renal artery; then passing ventrad between the testes with the corresponding vein, supplied the rectum, but did not anastomose with intestinal artery$_{(1)}$; while in still other specimens the posterior mesenteric artery was not observed; possibly, however, it was not injected. The posterior spermatic proper breaks up into numerous branches, which run along the posterior surface of the ovaries or penetrate the testes. The most posterior branch of the third spermatic artery is destined to supply the common oviduct or spermduct and sends off the *anterior urinary bladder artery* to the bladder. The *posterior urinary bladder artery* (Pl. I, figs. 1 and 10; Ur.B.A.) or the urinary bladder artery proper arises from the aorta directly behind the kidney, and in the specimen from which fig. 10 was drawn, a renal artery was given off to the kidney. In addition to supplying the urinary bladder this vessel usually sends off a branch to the great lateral muscle. It is probably a modified hæmal artery.

(*c*) *Comparisons of Hexagrammos, Scorpænichthys and Sebastodes.* — In these 3 different genera there is not nearly as much variation in the distribution of the dorsal aorta as there is in the distribution of the cardinal veins. *Hexagrammos* is identical with *Ophiodon.* In *Scorpænichthys* there are only 2 spermatic arteries, but what has been designated as the *urinary bladder artery* (Pl. IV, fig. 29; Ur.Bl.A.) arises much farther cephalad than the corresponding vessel in *Ophiodon*, and may in part be homologous to the posterior spermatic artery of *Ophiodon*, except that it does not supply the reproductive organs; running along the dorso-caudal surface of the kidney it passes between the suprarenal bodies and sends off a branch to each of them. (It will be noticed that the suprarenal glands are located much further dorsad on the kidney than they are in *Ophiodon.*). Then passing ventrad the urinary bladder artery passes behind the posterior mesenteric vein to supply the posterior part of the urinary bladder, and usually it is continued still farther ventrad to supply the rectum. In *Sebastodes* several changes are introduced, which are caused by the presence of the air-bladder and anterior spermatic arteries. Where the anterior spermatic artery is given off in *Ophiodon*, *Hexagrammos* and *Scorpænichthys* a similar vessel arises from the aorta in *Sebastodes;* this vessel, however, is destined to supply the air-bladder and is designated as the *posterior air-bladder artery* (Pl. IV, fig. 31; P.A.Bl.A.). In passing over the left side of the kidney it gives off several renal arteries and finally breaks up on the posterior end of the air-bladder. The single *spermatic artery* (Pl. IV, fig. 31; Sper.-A.), which performs part of the function of the urinary bladder artery of *Ophiodon* is given off from the aorta immediately in front of the point where the caudal vein penetrates the kidney. Near its source it sends off an intercostal artery (see fig. 31). It then follows along the posterior margin of the kidney, to the right of the caudal vein, and passing between the suprarenal bodies,[1] supplies each with a branch. The spermatic artery then continues ventrad between the kidney and the reproductive organs, gives off caudad the *urinary bladder artery* (fig. 31, Ur.Bl.A.), which is the only artery observed for the bladder. When the genital organs are reached, the spermatic artery anastomoses with the 2 anterior spermatic arteries already described under the head of the mesenteric artery.

VII. PERIPHERAL DISTRIBUTION OF THE VEINS.

The veins in general follow their corresponding arterial trunks, but not so closely as they do the nerves. There is much less literature on the veins than on the arteries. In Selachians where it is so much more difficult to inject the veins this is not strange, but with the Teleosts no more difficulty is experienced in injecting the veins. Generally the whole venous system can be satisfactorily injected from one point. (See under paragraph on technique).

1. *Jugular Veins.*

These large sinus-like vessels (Pls. I and II, figs. 1, 5, 15 and 16; J.V.), which are much longer than the corresponding common carotid arteries, arise in front of the prootic process from 3 principal trunks (see fig. 15). The external jugulars, coming from the facial region; the internal jugulars, coming from the eye, eye-muscles, and brain; and the orbito-nasal vein. Each jugular immediately enters the foramen formed by the prootic process and in its course through this foramen it is a rather small vessel lying directly above the external carotid

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[1] The suprarenal bodies are situated further caudad on the kidney than in *Ophiodon*.

artery, but upon emerging from this foramen rapidly increases in caliber. Then continuing caudad it passes over the efferent branchial arteries, and when the head kidney is reached follows along its ventral surface and terminates by anastomosing with the corresponding cardinal vein to form the great precaval trunk. Throughout its short course it receives numerous branches from the dorsal branchial muscles and the head kidney, which will be described in detail after considering the 3 principal trunks which go to make up the jugular vein.

(*a*) *External Jugular Veins* (Pls. I and II, figs. 1, 5 and 15; Ex.J.V.).— Of the 3 vessels which unite to form the jugular vein this is the largest. It also arises from 3 rather large trunks, the largest of which is the *facialis-mandibularis vein* (Pls. I and II, figs. 1 and 12; F.Man.V.). This vessel has its source in the anterior part of the lower jaw from the *genio-hyoideus vein* (Pls. I and II, figs. 1 and 12; Ghs.V.), which runs along the ventral surface of that muscle just outside of the corresponding artery, which is a branch of the left hyoidean artery. The facialis-mandibularis vein at first passes along the inner side of the dentary bone, receiving numerous branches from the mandibular portion of the adductor mandibulæ muscle. Shortly before leaving the articular bone it receives a large secondary mandibular vein, coming from the ventral side of the muscle, and a posterior branch coming from the inner side of the quadrate bone. The facialis-mandibularis vein then makes a dorsal bend; leaving the corresponding artery it follows up behind the ramus mandibularis V, or ramus maxillaris inferior of other authors, between the superficial and profundus portions of the adductor mandibulæ muscle, receiving several rather large branches from each. At the level of the levator arcus palatini muscle it receives, from the rear, the hyoidean vein.

Hyoidean Veins (Pls. I and II, figs. 1 and 12; Hyo.V.)— These vessels have their origin in the hyohyoideus superior muscles. Each vein runs along in that muscle some little distance ventrad of the hyoidean artery, which follows along on the surface of the arch. The vein receives a branch from the region of each branchiostegal ray and when the end of the arch is reached it curves cephalad, following along the interhyal, but above the minor hyoidean artery and the ramus hyoideus. When the preopercular is reached the course of this vein is dorsad behind the ramus hyoideus and when a little past the middle of the preopercular, it passes with the nerve to the outer surface of the hyomandibular through a foramen between the hyomandibular and the preopercular. Here it receives a ventral branch from the posterior part of the adductor mandibulæ muscle, which follows along the outer surface of the preopercular. The main stem then leaves the hyoidean ramus and continues obliquely cephalad a little ventrad of the levator arcus palatini and between the superficial and profundus portions of adductor mandibulæ, to unite with the facialis-mandibularis vein. The combined trunk proceeds dorsad for a short distance between the ramus mandibularis V and the facial artery to the floor of the orbit; where it receives the facialis-maxillaris vein.

Facialis-maxillaris Veins (Pls. I and III, figs. 1, 17, and 18; F.Max.V.). — Each of these vessels has its origin from a dorsal and a cephalic branch. The larger dorsal branch arises as an anastomotic vein from the orbito-nasal vein (see fig. 18); passing beneath the nasal sac some little distance cephalad of the corresponding artery it receives at the level of the ventral surface of the nasal sac a rather large vein coming from the region of the palatine arch; and then continuing ventrad a short distance the main stem passes under the maxilla artery and unites with the maxilla vein. The *maxilla vein* (Pls. I and III, figs. 1 and 17; Max.V.) has its source in a superficial and a profundus branch from the premaxilla, which unite in the region of the vomer. In its caudal course it receives several branches from the anterior part of the adductor mandibulæ muscle. After uniting with the dorsal branch from the region of the nasal sac the facialis-maxillaris vein proper crosses over the small facialis-maxillaris artery, and continuing caudad between the ramus maxillaris V or ramus maxillaris superior and the facialis-maxillaris artery in the adductor arcus palatini from which it receives several branches, it unites with the combined trunk of the mandibular and hyoidean veins in the posterior part of the orbit to form the external jugular trunk.

The facialis-maxillaris vein is much larger than the corresponding artery. It returns most of the venous blood from the region of the maxilla; while it is the orbito-nasal artery, which furnishes this region with most of its arterial supply.

The external jugular vein (Pls. I and II, figs. 1, 5 and 15; Ex.J.V.) is in itself a rather short trunk. It follows along in front of the truncus infra-orbitalis or truncus buccalis-maxillo mandibularis and the external carotid artery in the posterior part of the orbit; passing over the hyomandibular bone it unites with the orbito-nasal and internal jugular veins in front of the prootic process.

(*b*) *Internal Jugular Veins* (Pls. I and II, figs. 1, 13 and 15; In.J.V.). — What has been designated as the internal jugulars return the venous blood from the eye, recti muscles, and the brain. Each of these trunks might be said to have its source from the rectus, ophthalmic, and iris veins (see fig. 15) and at this point of union it also receives or sends off a large sinus-like vessel,[1] which extends caudo-mesad in the eye-muscle canal and anastomoses in the median line with a corresponding sinus-like vessel from the opposite internal jugular vein. This horse-shoe shaped sinus incloses the encephalic artery and receives a posterior branch from each of the external recti muscles. The main internal jugular vein becomes greatly reduced in caliber in passing through what might be called the internal jugular foramen (a foramen between the alisphenoid, prootic, and parasphenoid process, through which pass the internal jugular, the iris artery, and the ciliary nerve). Emerging from this foramen the internal jugular receives the encephalic vein, coming through the cranium through the small encephalic vein foramen (the most cephalic of the 3 foramina in the prootic, through which the encephalic vein and ciliary nerve pass). In front of the prootic process the internal jugular unites with the external jugular at an angle of about 75°. Coming in between these 2 trunks is the orbito-nasal vein, which might almost be said to unite with the internal jugular before it joins the external jugular.

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[1] This connecting sinus may be the same as the cross vessel connecting the two Bulbi ophthalmici described by Hyrtl (31, p. 236).

Rectus Vein (Pl. II, figs. 13 and 15; Rec.V.). — This vessel arises from a ventral branch coming from the inferior rectus muscle and a cephalic branch coming from the superior and internal recti muscles. Its course is then dorsad between the optic nerve and the superior rectus muscle, and it unites with the ophthalmic and iris veins to form the internal jugular trunk. The vein from the external rectus muscle empties into the iris vein and will be described more fully in connection with that vessel.

Ophthalmic Veins (Pls. I and II, figs. 1, 5, 13, 15 and 19; Oph.V.). — Each of these veins carries off the venous blood, which has become collected in the *choroid sinus.* This sinus (Pl. III, fig. 19; Chor.S.) is horse-shoe shaped, the anterior arm being much longer than the posterior one. It lies between the silver layer of the choroid and the similar shaped choroid artery, and occupying a large part of the space between the optic nerve and the choroid gland, drains the entire choroid coat and also the ventral portion of the iris. The venous blood from the dorsal part of the iris is returned by the iris vein proper, which will be described later on. The capillaries in the choroid may reach the choroid sinus in either of 2 ways. They may become collected into the *choroid veins* (Pl. III, fig. 21; Chor.V.), which break up into a fine rete mirabile of venous capillaries which run parallel with the arterial rete mirabile capillaries, and these in turn become collected entad into larger venous vessels that empty into the choroid sinus; or they may reach the choroid sinus directly by what I have designated as the *dorsal choroid vein* or the 2 *ventral choroid veins* (Pl. III, fig. 19; D.Chor.V. and V.Chor.V.), which empty into the anterior and posterior horns respectively. The vein returning the venous blood from the ventral portion of the iris is designated as the *ventral* or *minor iris vein* (Pl. III, fig. 19; Ir.V.$_{(1)}$). This vessel passes obliquely dorsad in the vascular layer of the choroid, directly cephalad of the ramus ciliaris brevis, and empties into the inner side of the anterior horn of the choroid sinus. No similar artery was observed and it is probable that the arterial supply for the ventral part of the iris comes from the ventral choroid arteries rather than from the iris artery.

The *ophthalmic vein* proper (Pls. I, II and III, figs. 1, 5, 13, 15 and 19; Oph.V.) arises as a sinus-like vessel from the dorsal region of the anterior horn of the choroid sinus, but gradually tapers down into its caudal course, and when immediately ventrad of the optic nerve receives a much smaller branch from the posterior horn. Curving around to the posterior side of the optic nerve it penetrates the silver layer of the choroid and the sclerotic coat. Once outside of the eyeball the ophthalmic vein pursues an oblique dorsal course, and, passing between the superior and external recti muscles it unites with the rectus and iris veins to form the internal jugular.

Iris or Ophthalmic Minor Veins (Pl. II and III, figs. 13, 15 and 19; Ir.V.).— A single iris vein arises from the capillaries in the dorsal part of the iris. Together with the ramus ciliaris longus and the iris artery it passes ventrad a short distance, between the silvery and vascular layers of the choroid (see fig. 19), and then penetrates the silvery layer and the sclerotic coat. After running along the posterior dorsal surface of the eyeball it passes between the superior and external recti muscles, but laterad to the ophthalmic vein. In its caudal course it receives a branch from the external rectus muscle, and finally terminates by uniting with the rectus and ophthalmic veins to form the internal jugular.

Optic or Retina Vein (Pl. III, figs. 19 and 20; Opt.V.).— In the specimen from which figs. 19 and 20 were drawn I noticed a small vein penetrating the sclerotic coat just ventrad of the optic artery. Its connection with the larger vessels had been destroyed before the vein was noticed, and internally the vein was not injected. Several specimens were injected especially to demonstrate this vessel, but in every case this vein failed to become injected. It is probable, however, that this vein follows the course of the optic artery, returning the venous blood from the lens, falciform process, and the retina, and very likely empties into the ophthalmic vein.

As has already been stated in the first paragraph under (*b*) the internal jugulars are connected with one another by a sinus-like vessel, which crosses the eye-muscle canal. Leaving the eye-muscle canal with the ciliary nerve and the iris artery, through what was designated as the internal jugular foramen, the internal jugular receives the encephalic vein shortly before uniting with the external jugular and orbito-nasal veins to form the jugular trunk.

Encephalic Veins (Pls. I, II, and III, figs. 1, 15, 23, 24, and 25: Enc.V.). — Each of these veins has its origin from 2 branches, an anterior and a posterior cerebral vein. The former returns the venous blood from the cerebrum, anterior surface of the optic lobes, optic and olfactory nerves; while the latter comes from the cerebellum, optic lobe, hypoaria, infundibulum, and the auditory region.

Anterior Cerebral Vein (Pl. III, figs. 23 to 25; A.Cer.V.). — Cephalad, this vein arises from a small vessel running caudad along the ventro-lateral surface of the olfactory nerve, and receives a branch from the olfactory lobe and one from the optic nerve. About midway between the olfactory and the optic lobes it unites with a much larger vein from the cerebrum. This vessel arises from the inner parts of the cerebrum, and, passing laterad between the cerebrum and the optic nerve, considerably caudad of the corresponding artery, it unites with the small cephalic vein just described. The combined vessel continues caudad a short distance and when opposite the optic lobes receives 2 or more branches coming from the anterior part of the hypoaria, infundibulum, hypophysis, and the anterior surface of the optic lobes. Then curving obliquely cephalad, the anterior cerebral vein proper crosses the III and IV nerves and the posterior cerebral artery to unite with the posterior cerebral vein in forming the encephalic trunk.

Posterior Cerebral Vein (Pl. III, figs. 23 to 25; P.Cer.V.). — This vein has its source from 3 principal branches, namely: the mesencephalic, cerebellum and auditory veins, the 2 latter vessels uniting between the hypoaria and the optic lobes, immediately before the mesencephalic vessel is received. The *auditory vein* (Pl. III, figs. 23, 23*a* and 25; Aud.V.) arises from branches coming from the utriculus, anterior and external ampullæ. The vein from the posterior ampulla empties into a branch of the posterior encephalic vein, and will be described under that vessel. Continuing cephalad for a short distance the auditory vein anastomoses with the *cerebellum vein* (Pl. III, figs. 23 and 25; Cer.V.), which arises in and leaves the cerebellum with the cerebellum artery, but below it. In its ventral course it receives a superficial branch from the posterior surface of the optic lobe, and, after uniting with the auditory vein, the combined trunk continues cephalad a short distance between the optic lobe and the hypoaria and ventrad of the posterior cerebral artery before receiving the mesencephalic vein (See fig. 23). The *mesencephalic vein* (Pl. III, figs. 23 to 25: Me. V.) arises from the floor of the mesencephalon (optic lobe) and penetrating ventrad through the crus, passes out between the optic lobe and the hypoaria, in front of the III nerve and mesencephalic artery, then crossing below the nerve and artery it unites with the common vessel formed by the anastomoses of the auditory and cerebellum veins to form the *posterior cerebral vein* (figs. 23 to 25; P.Cer.V.). The course of this vein is cephalad, directly below the posterior cerebral artery, between the optic lobe and hypoaria, and between the trigemino-facial complex and the IV nerve. Uniting with the anterior cerebral vein midway between the cerebrum and the optic lobe it forms the *encephalic vein* (Pls. I, II and III, figs. 1, 15, 23 and 25; Enc.V.), which shortly leaves the IV nerve to follow trigemino-facial complex, and when the facialis portion of the ramus lateralis accessorius is given off the *cranial cavity vein* is received. This vein (Pl. III, fig. 24; C.C.V.) follows along the anterior surface of this nerve and anastomoses caudad with a branch of the posterior encephalic vein, which follows along the posterior surface of the vagus portion of the ramus lateralis accessorius. Hence the venous blood from the adipose tissue of the cranial cavity may reach the jugular vein through the encephalic, or the posterior encephalic vein, or through both. Then leaving the trigemino-facial complex, along the inner surface of the ciliary nerve, the encephalic vein penetrates with it through the most anterior foramen in the prootic, and here empties into the internal jugular just before it unites with the orbitonasal and external jugular in forming the main jugular vein.

(*c*) *Orbito-nasal Veins* (Pls. I, II and III; figs. 1, 5, 13, 15, 17 and 18: O.N.V.).—Each of these veins has its origin directly behind the maxilla, and, following caudad along the ventral side of the corresponding artery, passes behind the nasal sac, where it receives 2 veins coming from the nasal sac. The smallest and most cephalic one is designated as the *anterior nasal sac vein* (Pl. III, figs. 17 and 18; N.S.V.$_{(1)}$). In the specimen from which figs. 17 and 18 were drawn this vessel arose from 6 anterior radial veins (see fig. 17). Each of these radial veins runs along the outer or distal edges of the secondary filaments of one of the primary filaments, and from each of these secondary filaments there comes a branch, which receives the capillaries from the inner connective tissue layer of that secondary filament and from that portion of the primary or radial filament. These radial filament veins unite with one another at their bases and finally terminate in the anterior nasal sac vein, which empties into the main orbito-nasal trunk. In like manner the larger *posterior nasal sac vein* (Pl. III, figs. 17 and 18; N.S.V.$_{(2)}$) arises from 8 posterior radial veins, which take their origin from the secondary filament veins from their respective radial or primary filament. The 2 nasal sac veins are usually distinctly separated as shown in fig. 17, but in a few cases I have noticed that they were connected by a longitudinal vein, thus forming a continuous lateral vein into which all the radial veins were emptied, and from which the 2 nasal sac veins had their source. Between these 2 nasal sac veins, the orbito-nasal vein anastomoses with a branch of the facialis-maxillaris vein (see fig. 18). After leaving the nasal sac, the orbito-nasal vein pursues a general caudal course, parallel with, but dorsad of, the orbito-nasal artery and mesad of the olfactory nerve, and enters the orbit through the olfactory foramen in the prefrontal. Once inside the orbit it leaves the olfactory nerve and the orbito-nasal artery to pursue, with the truncus supra-orbitalis or ramus ophthalmicus superficialis and profundus, a sort of dorso-caudal course through the orbit. Passing behind the superior oblique muscle it receives the *inferior oblique vein* (Pl. II, fig. 13: Inf.O.V.), coming up from the outside of that muscle, and the *superior oblique vein* (fig. 13: Sup. O.V.), coming down from the inside of that

muscle. Then continuing caudad, behind the superior rectus muscle and mesad of the truncus supra-orbitalis, it arrives in the posterior dorsal corner of the orbit, where it receives the *sclerotic vein* (Pl. II, fig. 15; Scl.V.). This vessel, which arises from the adipose tissue in the region of the anterior part of the eyeball, runs obliquely caudad across it, mesad of the corresponding nerve and artery. After receiving this branch, the main orbito-nasal vein crosses above the ophthalmic and iris vessels, and following around the eyeball for a short distance, finally comes in between and unites with the external and internal jugulars to form the great jugular vein.

The remarks made under the summary of the carotids apply with equal force to the external and internal jugular veins. These are simply arbitrary names given to the 2 largest veins of the head region, which go to make up the common jugular trunk.

2. *Vessels Emptying Directly into the Jugular or into the Head Kidney.*

a. Veins Emptying into the Kidney. — These veins include the posterior encephalic and the first and second neural veins. They do not empty at once into the jugulars, but penetrate the dorsal surface of the head kidney, break up into smaller vessels, which become reunited forming the renal veins, and these empty into the jugular vein.

Posterior Encephalic Veins (Pls. II and III, figs. 16, 23 to 25; P.Enc.V.).— These veins may be said to concur in part with the first neural or vertebral artery. Each of these veins arises from a superficial capillary network from the dorsal surface of the optic lobes; passing caudad over the cerebellum it receives a superficial branch from it and several from the adipose tissue surrounding the brain and the semi-circular canals; and usually anastomoses with the cranial cavity vein (see fig. 24), which empties into the encephalic vein. After passing over the cerebellum the posterior encephalic vein bends ventrad, following along behind the vagus portion of the ramus lateralis accessorius to its origin from the dorsal root of the vagus, and when the level of the oblongata is reached, sends off, or receives, a cross vessel from the corresponding vein on the opposite side. This cross vessel receives a branch, coming caudad along the dorsal surface of the oblongata. Whether it returns any of the venous blood from the cerebellum I was unable to determine. In the neighborhood of the origin of the vagus portion of the ramus lateralis accessorius from the dorsal root of the vagus, the posterior encephalic vein receives an anterior branch or *oblongata vein* (Pl. III, fig. 24; Obl.V.), which has its source from the side of the oblongata directly behind the roots of trigemino-facial complex, and shortly receives a branch from the posterior ampulla, then running along the side of the oblongata, passes beneath the IX and X nerves and finally terminates by emptying into the posterior encephalic vein. Following along the dorsal root of the vagus nerve the posterior encephalic vein leaves the brain case through the vagus foramen in the exoccipital, but before leaving the skull the large *myelonal vein* is received from the rear. This vessel (Pl. III, figs. 23 to 25; My.V.) arises on the dorsal surface of the myel as far back as the 9th pair of spinal nerves. After running along on the dorsal surface of the myel for a short distance it separates into a right and a left myelonal vein. Each of these vessels runs along the lateral surface of the myel, passing between the dorsal and ventral roots of the spinal nerves, finally terminating by emptying into the posterior encephalic vein. Along its cephalic course the myelonal vein receives numerous vessels from the myel, and sends across dorsal connecting branches, which unite with the corresponding vein on the opposite side. Although the myelonal vein empties into the posterior encephalic vein, still, not all of its blood reaches the jugular through that vessel, but some of it is carried off by the first 3 *spinal veins* (Pls. II and III, figs. 16 and 24; Sp.V.). These vessels pass out with each alternate pair of spinal nerves, and emptying into the neural veins, which in the case of these anterior veins penetrate the dorsal surface of the head kidney, and here break up into very small veins, which again become collected into vessels that empty into the jugular vein. The posterior encephalic vein is simply a modified spinal vein, which after leaving the skull through the vagus foramen, follows along behind the nerve and receiving the much smaller neural vein, penetrates the anterior dorsal corner of the head kidney (see fig. 16). Within the head kidney the posterior encephalic or the most anterior neural vein breaks up into very small veins, which again become collected and empty into the jugular vein.

(*b*) *Veins Emptying Directly into the Jugulars.* — Under this head belong the opercular and the 3 dorsal branchial muscle veins. The latter in addition to draining the branchial muscles receive also the dorsal nutrient branchial veins from the branchial arches. In *Ophiodon* these veins are always present, but vary considerably in their distribution. Perhaps the most common arrangement is shown in fig. 1.

Opercular Veins (fig. 1; Op. V.). — These veins arise on the inner side of the operculars; running dorsad behind the corresponding arteries, they curve ventrad, after leaving the dorsal edge of the operculars, and after receiving a branch from the levator operculi muscles of Vetter, empty into the jugulars a little behind the first dorsal branchial muscle veins.

Dorsal Branchial Muscle Veins (fig. 1; Br.M.V, only the second vein being lettered). — In the specimen from which fig. 1 was drawn, the first of these vessels had its source in, and received its principal supply from, the first *dorsal nutrient branchial vein* (fig. 1; D.N.Br.V.). This vessel arises a little below the dorsal bend, and is at first the most anterior of the 3 vessels in the dorsal part of the first branchial arch. In the arch it receives a *nutrient filament vein* (fig. 2; N.Fil.V.), coming from the inner margin of each filament. When the dorsal bend of the arch is reached, the first dorsal nutrient branchial vein crosses over and continues dorsad behind the first efferent branchial artery. Then following along the outer surface of the first obliquus dorsalis muscle from which it receives a branch, it penetrates with the IX nerve through the first levator arc. branch. internus muscle, and again crossing over the first efferent branchial artery shortly after the carotid is given off, finally empties into the ventral side of the jugular a little cephalad of the opercular vein. The second dorsal branchial muscle vein, in this specimen, takes its source from the union of the second and third dorsal nutrient branchial veins. The combined vessel thus formed passes dorsad behind the second levator arc. branch. internus muscle, and after receiving a branch from it and another from the second obliquus dorsalis muscle, terminates in the jugular. In this specimen the third and last dorsal branchial muscle vein arose from 2 branches. The most cephalic one is a dorsal nutrient branchial vein from the last branchial arch, and the other has its source from the pharyngo-clavicularis externus, pharynx, and the occipito-clavicularis muscle. The dorsal branchial vessel thus formed passes in a dorso-cephalic direction above the corresponding artery. After crossing the last efferent branchial artery it receives a good-sized branch coming from the last 2 internal branchial levator muscles, and then empties into the jugular directly behind the second dorsal branchial vein, but before emptying into the jugular it receives the *thymus vein* from the rear. This vein (fig. 1; not lettered) runs cephalad along the ventral margin of the gland, receives several branches from it, and shortly before reaching the anterior end of the thymus, curves ventrad; crossing over the posterior encephalic and jugular veins, finally terminates in the third dorsal branchial muscle vein shortly before the latter empties into the jugular. In another specimen from the one figured, the dorsal nutrient vein from the second branchial arch joined the first dorsal branchial muscle vein immediately after it had pierced the first levator arc. branch. internus muscle. The second dorsal branchial muscle vein took its origin from the third dorsal nutrient branchial vein and received branches from the third obliquus dorsalis muscle and the second levator arc. branch. internus muscle; while the third and last dorsal branchial muscle vein had its source from the fourth nutrient branchial vein and a branch coming from the fourth obliquus dorsalis muscle. The thymus vein emptied into the posterior encephalic vein, and the vein from the pharyngo-clavicularis externus, pharynx, and the occipito-clavicularis muscle, which is usually the source of the last dorsal branchial muscle vein, crossed the jugular and posterior encephalic veins and terminated in the thymus vein.

3. *Inferior Jugular Veins.*

These vessels return the venous blood from the ventral musculature of the head, heart, and ventral portion of the branchial arches and correspond in the main to the pharynx artery. The inferior jugular vein, however, does not become a paired vessel until near its termination in the precaval vein.

The inferior jugular vein may be said to arise from a small vein coming from the ventral surface of the tongue, the *lingual vein* (Pl. II, fig. 12; Lin. V.). This vein continuing caudad as the inferior jugular vein, passes in a median line above and between the hyohyoideus superior muscles, after which it receives 3 pairs of veins, the first pair coming from the outer posterior surface of the geniohyoideus muscles, the second from the inner surface of the hyohyoideus superior muscles (Pl. II, fig. 12; Hys.V.), and the third pair are the *ventral nutrient branchial veins* from the first branchial arch. The latter vessels (Pl. II, fig. 12; N.Br.V.) drain the ventral half of the first pair of arches. Each of them arises as a paired vessel in front of the first efferent branchial artery. The *nutrient filament veins* (Pl. I, fig. 2; N.Fil.V.) from one side empty into one of these branches and those from the opposite side into the other branch.[1] Further caudad these two branches unite forming a single nutrient branchial vein into which a few of the most ventral nutrient filament veins from both sides are poured. In front of this nutrient branchial vein, running along the cephalic margin of the arch, is another vein, which sends caudad cross-vessels that empty into the main ventral nutrient branchial vein. Continuing ventrad, cephalad of the efferent branchial trunk, the first ventral nutrient branchial vein empties into the inferior jugular vein. After collecting these veins the inferior jugular passes caudad, above the thyroid gland and the ventral aorta; receiving branches from the gland, other ventral nutrient branchial veins, and several small veins coming from the obliqui ventrales muscles. Emerging from the last pair of afferent branchial arteries the inferior jugular continues caudad, passing

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[1] It is of interest to note that the nutrient filament veins come from the inner margins of their filaments; while the nutrient filament arteries are distributed to the outer margins.

between the ventral aorta and the transversus ventralis muscle, and when the posterior edge of this muscle is reached, which is about midway between the last pair of afferent branchial arteries and the ventricle, the inferior jugular bifurcates into a very large *right* and a much smaller *left inferior jugular vein* (Pl. II, fig. 12; R and L.I.J.V.). The course of each of these veins is then obliquely caudad, running along the ventral side of the pharynx close to the pharyngo-clavicularis internus muscle. They terminate by emptying into their respective precaval veins. Throughout their course they receive branches from the pharynx, the phayngo-clavicularis internus and externus muscles, and shortly before dividing, the inferior jugular received branches from the pharyngo-hyoideus and transversus ventralis muscles, and the coronary vein.

The *coronary vein* (Pl. II, fig. 12; Cor.V.) arises from a dorsal and a ventral branch, which run parallel with their respective arteries. The dorsal vessel collects the venous blood from the anterior part of the ventricle and the bulbus arteriosus; while the ventral branch drains only the bulbus. About midway between the ventricle and the first pair of afferent branchial arteries these 2 branches unite on the left side of the ventral aorta in forming the main coronary vein, which finally empties into the inferior jugular shortly after it emerges from the last pair of afferent branchial arteries.

Beside this coronary vein, which drains the ventral aorta, bulbus, and anterior part of the ventricle there is another system of coronary veins, which terminate by emptying directly into the auricle. The outer layer of the ventricle is a mass of capillaries, which become collected on the ventral side into 4 or 5 veins that pass around to the dorsal side where some of them anastomose, forming 2 or 3 vessels, which penetrate the auricle close to the auriculo-ventricular valve. In one specimen several small veins were noticed to arise on, and penetrate the dorsal surface of the auricle.

In *Sebastodes melanops*, beside the large right and the smaller left inferior jugular veins, 2 other veins, laterad to these, were observed. They arose from the pharyngo-clavicularis internus and externus muscles, and passed caudad to empty into their respective precaval veins.

4. *Ventral Veins.*

These veins correspond to, and drain the region supplied by the posterior part of the ventral artery: namely, the ventral or pelvic fins, their muscles, and the ventral portion of the myotomes forming the thoracic walls. Considerable variation is shown in these veins, since they may arise as 2 rather large veins of equal size or one small vein and one large one, but the most common arrangement for *Ophiodon* is that shown in fig. 12.

The vessel designated as the *right ventral vein* (Pl. II, fig. 12; R.Ven.V.) is a deeper vessel than the ventral artery, and terminates in the left hepatic sinus. This vein may be said to have its source from 2 branches, a *right* and a *left ventral fin vein* (Pl. II, fig. 12; R. and L.Ven.F.V.), which have their origin in the right or left ventral fin ray canal. In these canals the veins run behind the arteries, and receive a branch from the center of each ray. Leaving the canal of the last rays each of these veins crosses above the corresponding ventral ray artery, and passes cephalad, for some little distance, between the ventral or pelvic superficial adductor muscle and the ventral myotomes. Then after uniting with its fellow, the combined trunk continues cephalad as the right ventral vein or the main ventral vein. Along its course this vein and its 2 branches receive numerous vessels. Soon after leaving the ventral fin canal, the left ventral fin vein receives a posterior ventral vein, which runs parallel with the corresponding artery. This branch receives several *ventral intercostal veins* (Pl. II, fig. 12; V.-Intc.V.) from either side. In addition to receiving a ventral intercostal vein from the septum between each alternate pair of myotomes, each ventral fin vein receives several branches from the superficial and profundus adductor muscles, and at least 2 branches, coming up between the pelvic bones from the superficial and profundus abductor muscles. The right ventral vein itself also receives at least 2 ventral intercostal veins from the right side. In the specimen from which fig. 12 was drawn the *left ventral vein* (L.Ven.V.) was a very short vessel, arising from several ventral intercostal veins from the left side, but in other specimens the left ventral vein was as large as the right, and the vessel designated as the *left ventral fin vein* (fig. 12;

L.Ven.F.V.) instead of uniting with the right ventral fin vein to form the right ventral vein, forms the principal venous supply for the left ventral vein.

In *Hexagrammos* and *Scorpænichtys* the ventral veins are essentially the same as the last case described under *Ophiodon*; namely, the 2 ventral veins are of equal size, receiving their venous supply from the right and left sides respectively. In *Scorpænichthys*, however, the right and left ventral fin veins do not leave the ventral fin ray canal with the artery from the last ray, as is the case with *Ophiodon* and *Hexagrammos*, but may leave the canal between any 2 rays, usually, between different rays in the 2 different fins. In *Sebastodes* these 2 veins are of equal size, but another condition is introduced. The 2 ventral fin veins leave the ventral fin canal with their respective arteries, anastomose, and the common trunk thus formed passes cephalad parallel with the ventral artery, between the two pelvic bones, and usually empties into the left ventral vein.

5. *Subclavian Veins.*

In *Ophiodon* there are 3 subclavian veins, returning the venous blood from the region of the pectoral arch. Two of these, coming from the outer or abductor muscles, unite in forming the subclavian sinus which empties into the sinus venosus in front of the precava, while the third one coming from the rays and the inner or adductor muscles, pierces the anterior fork of the kidney. This vessel does not empty directly into the cardinal trunk, but first breaks up into smaller vessels, which reach the cardinal through the renal veins.

Internal Subclavian or Subclavian Veins$_{(1)}$ (Pl. II, fig. 14; Sub.V.$_{(1)}$).—The vessel thus designated, in the main, corresponds with the internal subclavian artery. It receives its supply in part from the pectoral rays, and in part from the adductor muscles, situated on the inner side of the pectoral arch. This vessel has its origin from a dorsal and a ventral pectoral fin vein, which unite in the pectoral ray canal, thus forming a continuous vessel, which runs along behind the corresponding pectoral fin artery. Within this canal it receives a small vein returning the venous blood from each ray. In no 2 specimens did these 2 veins leave the pectoral fin canal in the same places; in fact, they were not the same in the 2 different fins of the same fish. In the fin from which fig. 14 was drawn the dorsal branch left between the seventh and eighth rays, counting dorso-ventrad, and the ventral branch left in the neighborhood of the fourteenth ray. Each of these branches proceeded dorsad, for some little distance, along the inner surface of the superficial pectoral adductor muscle, and each branch received numerous smaller branches from the superficial and profundus adductor muscles. Uniting on the level with the scapula foramen they form the internal subclavian trunk, which continues dorsad behind the subclavian artery. Shortly before the kidney is reached it curves caudad, and passing between the first few spinal nerves and the superficial adductor muscle, pierces the ventral surface of the corresponding fork of the kidney. Once within the kidney the internal subclavian rapidly decreases in caliber, by sending off branches that break up into capillaries, which finally reach the cardinal through the renal veins.

The vein designated as the *external subclavian* or *subclavian vein*$_{(2)}$ (Pl. II, fig. 14; Sub.V.$_{(2)}$) has its origin from the superficial and profundus pectoral abductor muscles, on the outer surface of the pectoral arch. Coming through the scapula foramen, cephalad of the external subclavian artery, it receives a branch from the profundus adductor muscle, and then runs for a short distance below and behind the precaval vein, where it receives the vein designated as the *subclavian vein*$_{(3)}$ (Pl. II, fig. 14; Sub.V.$_{(3)}$). This vein takes its source from 2 branches, one coming from the ventro-cephalic portion of the profundus abductor muscle, and the other from the similar part of the profundus adductor muscle. The former penetrates the coracoid foramen, and unites with the latter in forming the main subclavian vein$_{(3)}$, which passes dorsad along the inner surface of the profundus adductor muscle. Leaving this muscle, subclavian vein$_{(3)}$ unites with the external subclavian vein to form the *subclavian sinus* (Pl. II, fig. 12; Sub.S.), which empties into the sinus venosus directly behind the precaval vein, but before uniting with the external subclavian, it receives a vessel formed from a branch from the clavicle and the *sterno-hyoideus vein* (Pl. II, figs. 12 and 14: Ster.V.).

In *Hexagrammos* and *Sebastodes* the subclavians are essentially the same as in *Ophiodon*, except that no vessel corresponding to subclavian vein$_{(3)}$ was observed. In *Scorpænichthys* there were at least 3 *internal subclavian veins* (Pl. IV, fig. 30; Sub.V.$_{(1)}$); all of which broke up in the anterior fork of the kidney. The *external subclavian vein* in *Scorpænichthys* (Pl. IV, fig. 30; Sub.V.$_{(2)}$) instead of emptying into the sinus venosus, breaks up in the anterior fork of the kidney, cephalad of the internal subclavians.

6. *Hepatic Portal System.*

This system of veins returns most of the venous blood from the stomach, spleen, cæca and intestine. Some of the blood, however, from the posterior part of the stomach and intestine, reaches the right cardinal through the posterior mesenteric vein. This vein anastomoses with the portal system in at least two places. In *Ophiodon* there are 2 distinct portal veins, which terminate in the right and left lobes of the liver. The right portal returns the blood from the right side of the stomach, spleen, and a portion of the intestine; while the left portal drains the cæca, ventral portion of the stomach, and a portion of the intestine. In *Ophiodon* these 2 systems remain quite well separated; nevertheless, their branches anastomose in several places in the region of the posterior end of the stomach, but within the liver none of their branches unite. Each of the portals breaks up into capillaries in its respective lobe, which reunite in forming the right and left hepatic veins, and these vessels unite in a sinus before emptying into the sinus venosus.

(*a*) *Right Portal Vein* (Pl. I, figs. 1 and 2; R.Por.V.). — In *Ophiodon* the right portal trunk is in itself a very short vessel, having its source from 2 principal trunks, one of them being the right gastric vein, coming from the stomach, and the other branch a vein formed by the union of the splenic and intestinal vein$_{(1)}$. The *right gastric vein* (fig. 1, R.Gas.V.) has its origin in the posterior or cardiac portion of the stomach, where it anastomoses with branch Z of the posterior mesenteric vein (fig. 1, P.Mes.V.) and the posterior gastric vein, which is a branch of the left portal. The course of the right gastric vein is cephalad, below the right gastric artery and the right gastric ramus of the vagus. Throughout its course it receives numerous branches from the muscular coats of the stomach. Leaving the anterior part of the stomach it crosses above the corresponding artery and nerve, and the cœliac artery, and when about midway between the stomach and the caudal tip of the right lobe of the liver, directly behind a gland-like body marked G. it unites with *intestinal vein*$_{(1)}$. This vein (Pl. I, figs. 1 and 6: Int.V.$_{(1)}$) usually arises in the region of the rectum by anastomosing with branch Y of the posterior mesenteric vein (see fig. 1). In its cephalic course in the adipose tissue surrounding the intestine, lying below the corresponding artery, it ordinarily sends off from one to 3 branches, which empty into the right cæca vein or its posterior gastric branch. In the specimen from which fig. 1 was drawn 3 such vessels were given off. The 2 posterior ones emptied into the right posterior gastric vein and the anterior one into the right cæca vein. Throughout its entire course intestinal vein$_{(1)}$ receives numerous branches from the intestine and when the spleen is reached, which is in the neighborhood of the anterior or duodenum portion of the intestine, it receives a large vein from that organ. The *splenic vein* (Pl. I, figs. 1 and 6; Spl.V.) arises in the center of the spleen from a fan-like system of vessels, which unite in a common stem, that leaves the anterior part of the spleen with the splenic artery and soon empties into intestinal vein$_{(1)}$. Immediately after receiving the splenic vein, intestinal vein$_{(1)}$, usually, sends off or receives a *connecting vein* (Pl. I, figs. 1 and 6; C′.V′.), which unites with the anterior intestinal or duodenum vein, a branch of the left portal. In another specimen this vein was seen to arise from the splenic instead of the intestinal vein. Intestinal vein$_{(1)}$ terminates by uniting with the right gastric vein, in the neighborhood of the right lobe of the liver, to form the main right portal trunk. As has already been stated this vessel (Pl. I, figs. 1 and 11; R.Por.V.) is in itself a very short trunk, which penetrates the apex of the right lobe of the liver, and exhausts itself in that gland by breaking up into numerous *interlobular veins* (fig. 11, I.Lob. V.), which finally terminate in numerous venous capillaries.

Shortly before entering the liver, however, the right portal receives a vein from a gland-like body, marked G in fig. 1, and the anterior gall-bladder vein. The latter vessel (fig. 11, A. G.Bl.V.) arises from the anterior part of the bladder, and like the corresponding artery, anastomoses with the posterior gall-bladder vein.

In some cases, as was also noted with the corresponding artery, intestinal vein$_{(1)}$ does not always have its origin in the rectum and anastomose with the posterior mesenteric vein and the vessels emptying into the right cæca vein; but sometimes arises much further cephalad, and the part of the intestine usually drained by this vessel was poured into the posterior mesenteric vein and the veins emptying into the right cæca vein.

(*b*) *Left Portal Vein* (Pl. I, figs. 1, 6 and 11; L.Por.V.). — This is somewhat the larger of the two portals. In *Ophiodon* it has its source, principally, from the right and left pyloric cæca veins and intestinal vein$_{(2)}$. Of the 2 *pyloric cæca veins*, the *right* (Pl. I, figs. 1 and 6; R.Cæ.V.) is the larger. Beside receiving 3 or 4 large branches coming from the cæca it receives a *right*, and a *left posterior gastric vein* (Pl. I, figs. 1 and 6; R, and L.P.Gas.V.). The right vessel comes from the right and ventral side of the posterior or cardiac portion of the stomach, where its branches anastomose with those of the right gastric vein and branch Z of the posterior mesenteric vein. In the specimen from which figures 1 and 6 were drawn the right posterior gastric vein received 2 branches from intestinal vein$_{(1)}$ and the right pyloric cæca vein received a third one. In those specimens in which these vessels unite with both intestinal vein$_{(1)}$ and the right pyloric cæca vein or its posterior gastric branch it would be possible for the blood to flow in either direction, but it is probable that the least resistance is toward the pyloric cæca vein. Shortly before the right pyloric cæca vein unites with the left in front of the pylorus, it receives a small vein from the pylorus. Usually the *left pyloric cæca vein* (see Pl. I, figs. 1 and 6), is much the smaller. It receives about 2 branches from the cæca and one or 2 small ones from the pylorus. Both of the pyloric cæca veins run outside of their corresponding arteries and unite in forming the left portal trunk directly in front of the point of bifurcation of the cœliac artery. Near its origin from the union of the two pyloric cæca veins the left portal, or occasionally it is the right pyloric cæca vein, receives *intestinal vein*$_{(2)}$. This vein (Pl. I, figs. 1, 6 and 11; Int.V.$_{(2)}$) usually has its source from the ventral side of the intestine close to the rectum. Its course is cephalad in the adipose tissue below the intestine. Before going very far, however, it crosses to the upper side of the intestine, changing places with intestinal vein$_{(1)}$. Then proceeding cephalad above the artery until the duodenum is reached, it crosses over the intestine, intestinal artery$_{(1)}$, intestinal vein$_{(1)}$, the anterior part of the duodenum, the cœliac artery, and empties into the left portal close to its origin from the two pyloric cæca veins. Continuing cephalad for a short distance between the stomach and liver and to the left of the cœliac artery, the left portal receives the *anterior intestinal* or *duodenum vein* (Pl. I, figs. 1 and 11; A.Int.V.), which returns the blood from the anterior loop. The course of this vessel is at first directly behind the corresponding artery; then after passing under intestinal artery$_{(1)}$ and intestinal vein$_{(1)}$ it ordinarily gives off or receives the *connecting vein* (figs. 1 and 6; C.'V.'), a small vein which usually anastomoses with intestinal vein$_{(1)}$, a branch of the right portal. Then after passing over the anterior arm of the duodenum from which it receives a branch, it crosses the cœliac artery, and after following along behind the hepatic artery for a short distance terminates in the left portal. The left portal enters the dorsal surface of the liver through 5 large *radicals* or *terminal branches* designated by the letters a to e (figs. 6 and 11). These vessels immediately penetrate the large left lobe of the liver and break up into the *interlobular veins* (fig. 11; I.Lob.V.), which, in turn, break up into venous capillaries. Usually several veins from the ventral surface of the stomach, designated as *ventral gastric veins* (fig. 6; V.Gas.V.), empty into some of these radicals, and some of the ventral gastric veins often penetrate the dorsal surface of the liver and break up into venous capillaries without emptying directly into the portal system. The *posterior gall-bladder vein* (fig. 11; P.G.Bl.V.), which arises on the posterior dorsal surface of the bladder and anastomoses with the anterior gall-badder vein, empties into radical a of the left portal. This radical may also receive a similar, but smaller vein from the ventral surface of the bladder.

An interesting vessel in *Ophiodon* is the *left gastric vein* (Pl. I, figs. 1 and 6; L.Gas.V.), since it is not connected with the portal system but terminates directly in the precava. This vein has its origin in 2 branches from the left side of the stomach, on either side of the left gastric artery. The ventral branch is usually the larger; arising from the extreme posterior end of the stomach, its branches anastomose with those of branch Z of the posterior mesenteric vein. When the anterior portion of the stomach is reached the smaller left gastric branch crosses over the left gastric artery and joins the main stem of the left gastric, and the combined vessel passes forward above the left gastric ramus of the vagus and empties into the precava. Still another small gastric vein arises from the anterior dorsal surface of the stomach and terminates in the precava, above the main left gastric vein.

As in other vertebrates the intestinal, gastric, and cæca veins arise from capillaries in the connective tissue layer of the crypts and the larger branches run in the muscular layers. Within the liver the terminal branches or radicals of the two portals exhaust themselves in the *interlobular veins* (fig. 11, I.Lob.V.), which break up into venous capillaries, that reunite in forming the *central* or *intralobular veins*, from which the *sublobular veins* (fig. 11, S.Lob.V.) have their origin. The latter vessels are the radicals, which by uniting, form the 2 *hepatic veins* (fig. 11, R. and L.Hep.V.); which come from the right and left lobes respectively, and terminate in a *hepatic sinus* that enters the sinus venosus from the rear. In the liver the main trunks of the hepatic system lie beneath those of the portal system.

As in the arteries, most of the variation of the veins in this group occurs in the viscera. Nevertheless, all of the species examined had a distinct right and left portal, which break up in the right and left lobes respectively. In *Sebastodes* both portals terminate in a common portal. In *Hexagrammos* the right portal anastomoses with radical *a* of the left portal. In *Scorpænichthys* this union sometimes occurs, but with *Ophiodon* it has never been observed. However, both *Ophiodon* and *Scorpænichthys* have a connecting vein that interlinks these 2 systems in the region of the spleen.

(*c*) *Right Portal in Hexagrammos, Scorpænichthys and Sebastodes.* — In *Hexagrammos*, as with *Ophiodon*, this vessel (Pl. IV, fig. 27; R.Por.V.) has its origin from an intestinal, and a gastric vein. The *right gastric vein* (Pl. IV, fig. 27; R.-Gas.V.) is essentially the same as in *Ophiodon*, except that there is no posterior mesenteric vein for it to anastomose with on the apex of the stomach, and it runs on the opposite side of the artery from what it does in the other 3 genera. The vessel designated as *intestinal vein*$_{(1)}$ (Pl. IV, fig. 27; Int.V.$_{(1)}$) is the principal intestinal vein. It arises in the region of the rectum, but soon crosses over to follow along the posterior arm of the ileum from which it receives several branches before receiving the *splenic vein*[1] (fig. 27; Spl.V.), and another good-sized branch which drains the region supplied by intestinal artery$_{(2)}$. Passing cephalad, parallel with, but below the corresponding artery it crosses over intestinal vein$_{(2)}$, the anterior part of the intestine, the cœliac artery, radical *a* of the left portal, and when the stomach is reached unites with the right gastric vein to form the *right portal* (fig. 27, R.Por.V.), This vessel immediately passes under intestinal artery$_{(1)}$, between the cœliac and right hepatic arteries, along the posterior surface of the gall-bladder, but behind the right hepatic artery. Here it receives a few small branches from the bladder and terminates in 2 or 3 small branches in the right lobe of the liver, and also anastomoses with radical *a* of the left portal.

In *Scorpænichthys* the *right portal* (Pl. IV, fig. 29; R.Por.V.) has its source entirely from the right gastric and the splenic veins. All of the intestinal veins empty into the left portal. The *right gastric vein* (fig. 29, R.Gas.V.) is practically the same as in *Ophiodon*; arising in the cardiac end of the stomach,

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[1] In *Hexagrammos* the spleen is located much further caudad than is the case with any of the other genera studied. Its position is much nearer the vent than the stomach.

it anastomoses with branch Z of the posterior mesenteric, and the posterior gastric veins. The *splenic vein* (fig. 29, Spl. V.) leaves the anterior surface of the spleen, which is located directly above the pylorus, and passes forward to unite with the right gastric vein in forming the right portal, but immediately after leaving the spleen it receives the *posterior gastric vein* (fig. 29, P.Gas.V.), which in *Ophiodon* emptied into the right cæca vein, a branch of the left portal. The right portal, itself, is almost identical with the same vessel in *Ophiodon;* it receives a small vein from a gland-like body marked G, and shortly before entering the right lobe of the liver receives the anterior gall-bladder vein which does not anastomose with the posterior gall-bladder vein as in *Ophiodon.* Usually the right portal breaks up in the small right lobe of the liver without anastomosing with terminal branch *a* of the left portal.

Beside the ordinary branches which go to make up the right portal in *Ophiodon*, there is an additional one in *Sebastodes*, namely, the *anterior air-bladder* or *air-bladder retia mirabilia vein* (Pl. IV, fig. 31; A.Bl.V.). This vessel arises from the retia mirabilia venous capillaries, which are continuous with, and run parallel to, the corresponding arterial retia mirabilia capillaries. These venous capillaries unite in forming larger vessels that terminate in the main anterior air-bladder vein, which pierces the ventral wall of the bladder and empties into the *right gastric vein.* The latter vessel, as in *Hexagrammos*, has its origin in the posterior end of the stomach without having any posterior mesenteric vein with which to anastomose. Shortly after receiving the anterior air-bladder vein the right gastric receives the vessel designated as intestinal vein$_{(1)}$. This vessel (fig. 31, Int.V.$_{(1)}$) arises in the rectum and drains the posterior portion of the intestine. In its cephalic course, parallel with the corresponding artery, it follows along the posterior border of the spleen; in *Sebastodes flavidus* (fig. 33) it was seen to unite with the splenic vein as in *Ophiodon*, while in *Sebastodes auriculatus* both vessels emptied separately into the right gastric vein. Shortly before joining the right gastric, or splenic vein as it is in *S. flavidus*, intestinal vein$_{(1)}$ usually receives a posterior gall-bladder vein (figs. 31 and 33, P.G.Bl.V.)

and an anterior intestinal vein. Soon after leaving the spleen, in front of the corresponding artery, the *splenic vein* (fig. 31, Spl.V.) receives the *posterior gastric vein* (fig. 31, P.Gas.V.) from the rear. This vessel arises from the ventral surface of the stomach immediately behind the pylorus, and receives a small branch coming from the ventral surface of the posterior end of the intestine. After receiving this branch the posterior gastric vein passes between the spleen and the cæca and joins the splenic vein. The splenic vein in *Sebastodes auriculatus* after crossing intestinal vein$_{(2)}$, and intestinal artery$_{(2)}$ unites with the right gastric component, directly below intestinal vein$_{(1)}$, to form the main right portal. Shortly before entering the liver the right portal receives a small branch coming from a gland-like body marked G (figs. 33 and 34), anastomoses with the common portal trunk (which will be fully described under the head of the left portal), and in its course in the right lobe of the liver receives the *anterior gall-bladder* vein. This vessel (figs. 33 and 34, A.G.Bl.V.) is always present, and sometimes returns the entire blood from the gall-bladder. Its course is to the right and above the ductus choledochus.

(*d*) *Left portal vein in Hexagrammos, Scorpænichthys, and Sebastodes.* — In *Hexagrammos* the two pyloric cæca veins are essentially the same as in *Ophiodon*, except that neither of them receives a posterior gastric vein from the cardiac end of the stomach. Close to its origin from the two pyloric cæca veins the *left portal* (Pl. IV, figs. 27 and 28; L.Por.V.) receives a branch from the anterior arm of the ileum, designated as intestinal vein$_{(2)}$ (fig. 27, Int.V.$_{(2)}$), but which perhaps corresponds to an elongated anterior intestinal or duodenum vein. On the dorsal surface of the liver the left portal breaks up into 3 radicals (figs. 27 and 28, *a*, *b* and *c*). Radical *a* is prolonged to anastomose with the right portal, and soon after leaving the main stem receives a very large *ventral gastric vein* (fig. 28, V.Gas.V.), which may to some extent take the place of the absent left gastric vein.

In *Scopænichthys* the *left portal* (Pl. IV, figs. 29 and 30; L.Por.V.) receives both of the intestinal veins. The pyloric cæca veins are essentially the same as in *Ophiodon*, except that the pyloric branch of the left one extends backward on the cardiac portion of the stomach as a sort of posterior gastric vein, and anastomoses with branches of the posterior mesenteric vein; while the posterior gastric vein proper empties into the splenic vein instead of the right cæca vein as in *Ophiodon*. *Intestinal vein*$_{(1)}$ (fig. 29, Int.V.$_{(1)}$) arises from the posterior end of the iliac loop; the most dorsal of its branches anastomoses with branch Z of the posterior mesenteric vein, and it receives a branch coming from the region of the rectum. In its cephalic course, intestinal vein$_{(1)}$ passes between the two arms of the ileum, and receives a branch from the posterior part of the intestine designated as *intestinal vein*$_{(2)}$ (fig. 29, Int.V.$_{(2)}$), and the *anterior intestinal* or *duodenum vein* (fig. 29, A.Int.V.). The combined intestinal trunk thus formed passes under the anterior arm of the duodenum and joins the left portal close to its origin from the 2 pyloric cæca veins, but before emptying into the left portal it receives or sends off a *connecting vein* (fig. 29, C′.V′.) that unites with the splenic vein. After reaching the great left lobe of the liver the left portal immediately gives off to each side numerous terminal branches or radicals, which break up into the interlobular veins. As in *Ophiodon*, except in a very few cases, radical *a* of left portal does not anastomose with the right portal; it, however, receives the *posterior gall-bladder vein* (fig. 30. P.G.Bl.V.), and also a very large *ventral gastric vein* (fig. 30, V.Gas.V.), which anastomoses anteriorly with the left gastric vein and posteriorly with a branch of the posterior mesenteric vein.

As in *Ophiodon* there is a *left gastric vein* (fig. 30, L.Gas.-V.) emptying directly into the precava and two smaller left gastric veins; one of which empties into the precava and the other into the left fork of the kidney; while the main left gastric vein anastomoses with branches of the ventral gastric vein, which has branches that anastomose with branches of the posterior mesenteric vein.

The *left portal* in *Sebastodes* (Pl. IV, figs. 30 and 31; L.-Por.V.) is a rather insignificant vessel, having its source from a vessel designated as intestinal vein$_{(2)}$ and the right pyloric cæca vein. Intestinal vein$_{(2)}$ (fig. 31, Int.V.$_{(2)}$) returns the blood from the ileum: passing beneath intestinal vessels$_{(1)}$ and the splenic vessels, it crosses under the anterior part of the spleen, where it joins a common trunk formed by the union of the right pyloric cæca vein and a very large *pylorus vein* (fig. 32, Pyl.V.). The common trunk thus formed is the left portal, but instead of breaking up into numerous radicals it empties with the *left pyloric cæca vein* (fig. 32, L.Cae.V.) and the *ventral gastric vein* (fig. 32, V.Gas.V.) into the *common portal vein* (fig. 32, C.P.V.). By anastomosing with the common portal, the right portal might also be said to empty into the common portal.

Summary of the Portals.—As in the case with the corresponding arteries, intestinal veins$_{(1 \text{ and } 2)}$ are arbitrary names given to the two principal intestinal veins. Considerable variation occurs in these two veins in the same species, but in *Ophiodon* the vessel designated as intestinal vein$_{(2)}$ arises in the posterior part of the intestine, and in its cephalic course along the ventral side of the intestine receives the splenic vein, and joining the right gastric vein forms the right portal. The corresponding vein in *Hexagrammos* pursues a similar course; while in *Scopænichthys* the two intestinal veins unite and empty into the left portal; and in *Sebastodes* intestinal vein$_{(1)}$ drains only the posterior part of the intestine, and may unite with the splenic vein, or each of these vessels may empty separately into the right gastric vein to form the right portal. In every case the right portal breaks up in the right lobe of the liver. The vessel designated as intestinal vein$_{(2)}$ in *Ophiodon* arises from the ventral posterior end of the intestine and terminates in the left portal. In *Hexagrammos* this vessel might possibly correspond to an elongated duodenum artery; while in *Scorpænichthys* if this vessel is represented at all, it unites with intestinal vein$_{(1)}$ and the combined trunk empties into the left portal; and in *Sebastodes* this is the principal intestinal trunk, arising from the iliac loop it unites with the right pyloric cæca vein to form the left portal trunk. All the genera but *Hexagrammos* have a posterior gastric vein; in *Ophiodon* it terminates in the right pyloric cæca vein; while in *Scorpænichthys* and *Sebastodes* it empties into the splenic vein, a branch of the right portal.

Ophiodon and *Scorpænichthys* have a left gastric vein, which empties into the precava: while in *Sebastodes* and *Hexagrammos* the ventral gastric veins are greatly enlarged, and evidently to some extent take the place of this vessel, nevertheless in *Scorpænichthys* the ventral gastric is a good sized vessel and anastomoses with the right gastric vein. In *Ophiodon* and *Scorpænichthys* there is a grand anastomosis in the cardiac portion of the stomach of the branches of the right gastric, left gastric, ventral gastric, posterior gastric and posterior mesenteric veins. Usually the right and left pyloric cæca veins unite to form the left portal, but in *Sebastodes* the right pyloric cæca vein joins intestinal vein$_{(2)}$ to form the left portal, and the left pyloric cæca vein empties into the common portal trunk. *Ophiodon* and *Scorpænichthys* have a connecting vein in the region of the spleen that links the 2 portal systems; in *Ophiodon* it usually connects intestinal vein$_{(1)}$ with the anterior intestinal or duodenum vein; while in *Scorpænichthys* it connects the splenic and common intestinal veins. Within the liver the 2 portals are usually distinctly separated in *Ophiodon* and in *Scorpænichthys;* while in *Hexagrammos* radical *a* of the left portal anastomoses with the right portal; and in *Sebastodes* both portals together with the ventral gastric and left pyloric cæca veins unite in forming a common portal trunk, which gives off numerous radicals that break up into the interlobular veins.

7. *Renal Portal System.*

Like the hepatic portal system the renal portal system consists of two principal venous trunks, which are connected by a system of venous capillaries within the kidney. One of these trunks, the caudal vein, arises in the region of the tail and pursues a cephalic course in the hæmal canal, immediately below the caudal artery, receiving the neural veins from above and the hæmal veins from below. Piercing the dorsal surface of the kidney it bifurcates into a right and left renal portal vein; each of these sends off numerous afferent renal veins that after breaking up into capillaries reunite in numerous efferent renal veins, which terminate in, and form, the right cardinal vein. This trunk starts in the posterior end of the kidney, passing cephalad through the center of this organ; it follows the right fork of the kidney and unites with the right jugular to form the right precava. Throughout its course it receives numerous branches, which will be described in detail later on. There is also a smaller left cardinal for the left lobe of the kidney, which will also be considered under a separate head.

(*a*) *Caudal Vein* (Pl. I, figs. 1, 7, 8, 9 and 10; Cau.V.).—This trunk has its origin in the region of the last vertebra from a right and left branch; both of which have a more superficial course than the corresponding arteries. The *right caudal vein* (fig. 7, R.Cau.V.) is much the shorter; it arises from the region of the tail and passes cephalad between the superficial and profundus muscles, and when the last vertebra is reached, curves inward, and after receiving a dorsal branch joins the larger *left caudal vein.* The latter vessel (figs. 1 and 7; L.Cau.V.) has its origin from a dorsal and a ventral branch in the caudal fin ray canal. These branches lie immediately behind the corresponding lymphatic and arterial vessels. They receive a branch from the central canal of each ray, coming from the fin membrane and the fin ray muscles. Uniting between the two hypural bones the dorsal and ventral branches form the *left caudal vein* (figs. 1 and 7, L.Cau.V.), which passes cephalad between the superficial and profundus caudal fin muscles, receiving branches from each. In the region of the last vertebra it receives a dorsal branch and curves inward to unite with the right caudal vein, but before joining the left caudal vein to form the main caudal vein, each of the caudal veins appears to receive a vessel from the caudal lymphatic sinus. The course of the caudal vein is cephalad in the hæmal canal, immediately below the caudal artery; and in its course to the kidney receives a dorsal branch from in front of each alternate neural spine, and a ventral branch from in front of each alternate hæmal spine.

Each *neural vein* (fig. 1; Neu.V.) has its origin from a cephalic and a caudal branch; the latter returns the venous blood from superficial and profundus levator and depressor muscles of that ray; while the former returns the blood from the corresponding muscles of the preceding ray, and each branch receives a vessel coming from behind the ray. These 2 branches unite at about the level of the apex of the neural spine, forming the neural vein proper. At this point the neural vein receives the *dorsal lateral vein* (fig. 1; D.Lat.V.), returning the blood from the dorsal region of the 2 neighboring myotomes, and immediately after receiving this branch the neural vein passes obliquely ventrad between the neural lymphatic vessel and the neural spine. Then curving forward and outward it crosses the neural canal, the centrum, the dorsal aorta, and empties into the caudal vein. In crossing the vertebral column it receives a *spinal vein*, coming through the spinal foramen from the myel, and the *median lateral vein* (fig. 1; M.Lat.V.), returning the blood from the central region of the 2 adjacent myotomes. The *hæmal veins* pursue a similar course from the ventral side of the body. Each of these vessels (fig. 1; Hæ.V.) has its source from the superficial and profundus levator and depressor muscles of 2 successive anal rays. In the region of the apex of the hæmal spine it receives the *ventral lateral vein* (fig. 1; V.Lat.V.), coming from the ventral portion of the two adjacent myotomes. Then passing obliquely dorsad between the hæmal lymphatic vessel and the hæmal spine it empties into the caudal vein. This is the normal arrangement of a neural or a hæmal vein; occasionally, however, a neural or a hæmal vein may drain the region of 3 or even 4 myotomes, and a neural vein may cross either side of the vertebral column. Usually between the first and second caudal vertebræ the caudal vein receives the *urinary bladder vein* (figs. 1 and 10: Ur.B.V.), coming from the posterior surface of the bladder. Very often, however, as is shown in fig. 10, this vein does not empty into the caudal vein, but penetrates the posterior ventral end of the kidney and reaches the cardinal through the renal veins.

After passing through the hæmal canal of the first caudal vertebra the caudal vein curves ventrad and pierces the dorsal surface of the kidney and becomes the renal portal vein.

Shortly after the caudal vein, or renal portal as it really is, penetrates the kidney it receives a rather large trunk designated as the *posterior mesenteric vein* (Pl. I, figs. 1 and 10: P.-

Mes.V.). This vessel arises from 2 good sized branches designated as Y and Z (see fig. 1). Branch Z which is strictly a gastric vein, takes its origin from several branches coming from the posterior or cardiac end of the stomach; one of which anastomoses with the right gastric vein; and 2 other branches anastomose with branches of the left gastric and posterior gastric veins. The course of branch Z is dorso-caudad; passing to the left of the intestine and its vessels, it unites with branch Y directly below the reproductive organs. Branch Y, which is distinctly an intestinal vein, drains the posterior end of the intestine, and usually anastomoses with intestinal vein$_{(1)}$; passing caudad it joins branch Z in forming the main posterior gastric stem, which passes between the reproductive organs, without receiving any branches, penetrates the posterior ventral surface of the kidney, and passing to the left of the right cardinal empties into the renal portal vein. It would be possible for the blood in the posterior mesenteric to flow in either direction, but it is probable that the least resistance is toward the kidney.

After receiving the posterior mesenteric vein the caudal or renal portal vein bifurcates into a *right* and a *left renal portal vein* or *vena renalis advehens* (figs. 1 and 10; Ren.P.V.). These trunks run cephalad for some little distance through the dorso-lateral part of the kidney, and gradually decrease in caliber by giving off numerous ventral branches, the *afferent renal veins* or *venae renales advehentes* (figs. 1 and 10, A.Ren.V.). These vessels break up into rather coarse venous capillaries near the lateral surface of the kidney, and become collected ventrad and mesad by the small *efferent renal veins* or *venae renales revehentes* (figs. 1 and 10; E.Ren.V.). A cross section through an injected kidney hardened in formalin shows us that these vessels, many of which are visible from the ventral side of the kidney, empty into the right cardinal from every direction.

(*b*) The *right cardinal vein* (Pl. I, figs. 1, 5 and 10; R.Car.V.), which is the principal cardinal has its source mainly from the efferent renal veins; it arises in the extreme caudal end of the kidney, below the caudal vein, and passes cephalad through the center of the kidney until the kidney forks, when it follows the right fork. In the region of the last branchial arch it unites with the right jugular in forming the *right precava* (Pls. I and II, figs. 5 and 12; Prec.V.) or the *ductus Cuvierii* as it is often called, which encircles the right side of the œsophagus and empties into the sinus venosus in front of the subclavian sinus.

(*c*) *Other Vessels Emptying into the Kidney.* — Beside the posterior mesenteric and caudal veins there are several other vessels, which penetrate the kidney and reach the right cardinal in one way or another.

First under this head might be mentioned the *spermatic veins.* In the female (fig. 1) numerous branches arise from the lateral surfaces of the ovaries and unite in a longitudinal vessel, that has its origin from the anterior surface of the urinary bladder and the oviduct. From this longitudinal vessel at least two spermatic veins (fig. 1; Sper.V.) have their origin; passing dorsad they terminate in one way or another in the kidney: they may empty directly into the right cardinal, or the renal portal vein, or they may reach the right cardinal through the efferent renal veins. In the male (see fig. 10) there is no longitudinal trunk, and the spermatic veins arise directly from numerous branches coming from the inner surface of the testes. In this specimen the most anterior spermatic vein emptied into an afferent renal vein, the second one broke up into capillaries, and the last 2 joined the posterior mesenteric vein within the kidney. The *neurals* as in the caudal region drain the region of 2 myotomes, passing ventrad between the neural lymphatic vessel and the neural spine, they penetrate the dorsal wall of the kidney, but instead of emptying directly into the right cardinal, break up into capillaries that reunite in the efferent renal veins. The *intercostal veins* (fig. 1; Intc.V.) corresponding to the hæmal veins of the caudal region, arise from 2 myotomes of the thoracic walls: passing dorsad behind the intercostal lymphatic vessel they penetrate the ventro-lateral edge of the kidney, break up into capillaries, and reach the right cardinal through the efferent renal veins. In the cephalic part of the thoracic wall they anastomose ventrally with the ventral intercostal veins. Usually, there are 2 *suprarenal veins* (fig. 10, Sr.V.), which pass inward and join the right cardinal.

(*d*) The *left cardinal vein* (figs. 1 and 5; L.Car.V.) is a very short and unimportant vessel; having its source entirely from the anterior end of the left fork of the kidney. The blood from the posterior part of this fork reaches the heart through the right cardinal. The left cardinal unites with the left jugular in forming the left precava, which passes around the left side of the œsophagus and terminates in the sinus venosus.

(*e*) *Renal Portal System in Scorpænichthys, Hexagrammos and Sebastodes.* — In each of these genera the renal portal system is in the main substantially the same. Some minor variations are noted in the 3 following paragraphs.

The renal portal system in *Scorpænichthys* is essentially the same as in *Ophiodon*. The caudal vein after passing through the hæmal canal of the first caudal vertebra penetrates the dorsal surface of the kidney, and breaks up into two renal portal veins. As in *Ophiodon* a *posterior mesenteric vein* (fig. 29, P.Mes.V.) is also present, which arises from a gastric and an intestinal branch, and after passing over the urinary bladder from which it receives a branch, penetrates the posterior apex of the kidney, terminating in the renal portal; but the distance it has to go cephalad in the kidney is much greater than in *Ophiodon*, and numerous branches are given off, which reach the cardinal through the efferent renal veins; so that the posterior mesentric vein is much reduced in caliber upon joining the renal portal. It is of interest to note in this connection that in *Enophrys* and *Calycilepidotus*, 2 genera of the family Cottidæ, no such vessel as the posterior mesenteric was noticed. As regards the spermatic veins, they are also of especial interest, coming in midway between *Ophiodon* and the peculiar arrangement found in *Sebastodes*. In the female there is a *right* and a *left spermatic vein* (fig. 29, R. and L.Sper.V), each of which receives numerous branches coming from the lateral surfaces of their respective ovaries. From each of these longitudinal veins there arise a cephalic and a caudal vessel; both of which unite with corresponding vessels from the opposite side to form the *spermatic veins* proper (fig. 29; Sper.$V._{1 \text{ and } 2}$), and each of these veins empties directly into the right cardinal, which in *Scorpænichthys* runs along the ventral surface of the kidney. In both male and female the right and left spermatic veins are continued some little distance cephalad of the reproductive organs, and empty into their respective cardinal veins, a little behind the point of union of the cardinals with the jugulars to form the precava.

The *caudal vein* (fig. 27; Cau.V.) in *Hexagrammos* after passing through the first caudal vertebra gives off an *anterior* and a *posterior renal portal vein* (fig. 27; Ren.P.V.) The former is the principal renal portal vein; it continues cephalad along the dorsal surface of the kidney, and breaks up into numerous afferent renal veins. In one specimen this vein appeared to empty directly into the right cardinal vein. The smaller posterior renal portal breaks up in the caudal end of the kidney. One of its branches receives the vein designated as the *urinary bladder vein* (fig. 27; U.Bl.V), which may to some extent be analogous to the posterior mesenteric vein of *Ophiodon* and *Scorpænichthys;* it has its source from a meshwork of small veins on the rectum, which anastomose with branches of intestinal vein$_{(1)}$; passing across and along the dorsal surface of the bladder from which it receives several branches, it pierces the ventro-caudal end of the kidney, and gives off several branches in the kidney before uniting with a branch of the renal portal. The *right cardinal* (fig. 27; R.Car.V.) as in the other genera arises in the extreme posterior end of the kidney, and passing cephalad close to the ventral wall, unites with the right jugular in the right fork of the kidney to form the right precava. The veins from the caudal region of the ovaries empty into a longitudinal vessel that passes between the ovaries; farther forward this vein bifurcates, one branch running along the dorsal surface of the left ovary and the other along the right; both of them receiving numerous branches from the lateral surfaces of their respective ovaries. From the right longitudinal spermatic vein there arise an anterior and a posterior branch, both of which unite with the corresponding branches from the left longitudinal spermatic vein in forming the main *anterior* and *posterior spermatic veins* (fig. 27, Sper.V.$_{(1)\text{ and }(2)}$) which empty directly into the right cardinal.

All species of *Sebastodes* examined had a distinct renal portal system, which in the main resembled *Ophiodon;* however, the renal portal veins extend much further cephalad, there is always one or more posterior air-bladder veins emptying into the renal portal system, and there is no posterior mesenteric vein. The kidney itself differs considerably in shape from that of the other genera; while it usually occupies a large portion of the dorsal part of the short thoracic cavity, still a large portion of the organ is crowded cephalad into the two forks. The *caudal vein* (Pl. IV, fig. 31; Cau.V.) after piercing the posterior dorsal side of the kidney continues cephalad along the dorsal surface of the kidney for some little distance as a *renal portal vein* and not until the kidney forks does this vein separate into the *renal portal veins* (fig. 31, Ren.P.V.). These veins continue cephalad in their respective lobes until near the point of union of the cardinals with the jugulars, giving off numerous afferent renal veins, and the renal portal itself receives the following vessels. First, the *spermatic vein* (fig. 31; Sper.V.), which is formed from the posterior union of the right and left spermatic veins. In its dorsal course about midway between the reproductive organs and the kidney it receives the *urinary bladder vein* (fig. 31; Ur.Bl.V.), and immediately before emptying into the renal portal, a small *suprarenal vein.* Shortly after receiving the spermatic, the caudal or renal portal receives a rather large *posterior air-bladder vein* (fig. 31: P.A.Bl.V.), which arises from a regular network of vessels on the posterior end of the air-bladder. In the specimen from which fig. 31 was drawn, two smaller posterior air-bladder veins were also noticed; one of which terminated in the renal portal vein, and the other in the right cardinal. Usually, however, there is but one posterior air-bladder vein, and it may empty into either the right cardinal or the renal portal vein. The right cardinal is almost identical to the similar vessel of the other genera, and a description of it is unnecessary.

VIII. VASCULAR SYSTEM IN ANOPLOPOMA.

Three specimens of this species were brought in by Chinese fishermen when this paper was about finished. All were injected, but only one satisfactorily, the other specimens having been badly torn by the hooks. Upon dissection several interesting variations were noticed, and it seemed desirable to include a representative of the family *Anoplopomatidæ* in this paper.

Carotid Arteries.—In *Anoplopoma* there are no common carotids; both carotids arise separately from the dorso-cephalic corner of the first efferent branchial artery. The *internal carotid* (fig. 35; I.Car.A.), which is given off first, presents no peculiarities. While the *external carotid* (fig. 35; E.Car.A.) is a much smaller vessel than in the other genera, and simply supplies the facial region without anastomosing with the hyoidean artery to form the mandibular artery; it immediately gives off the vessel designated as the *pseudobranchial* or *afferent pseudobranchial artery* (fig. 35; Ps.A.), which is as large as the external carotid, and which might be said to arise with the external carotid from the first efferent branchial artery. The course of the pseudobranchial artery is ventrad behind the hyomandibular, exhausting itself by giving off numerous afferent pseudobranchial filament arteries. Near its distal end the pseudobranchial artery receives the dorsal branch of the hyoidean artery, and it is probable that the hyoidean artery furnishes the pseudobranch, especially the ventral part of it, with some of its blood supply, but most of it evidently comes from the pseudobranchial artery, which is much larger at its source from the external carotid than at the point of anastomosis with the hyoidean artery. This arrangement somewhat resembles the pseudobranchial supply in *Gadus*, according to Müller (50) and Parker (61), but differs from it considerably. In *Gadus* the afferent pseudobranchial artery is a branch of the hyoidean artery, and the dorsal continuation of the main stem, which is much reduced in caliber, anastomoses with the internal carotid of the circulus cephalicus.

Hyoidean Arteries (fig. 35: Hyo.A.).— One of the most striking differences in the circulatory system of *Anoplopoma* is in connection with this vessel. As in *Ophiodon* each hyoidean artery has its origin from the ventral ends of the first efferent branchial artery. Passing along the dorsal surface of the hyoid arch it gives off the characteristic branch to the branchiostegal rays and then follows along in front of the interhyal, but when the preopercle is reached, instead of passing through a foramen formed by the symplectic, hyomandibular, and preopercular and anastomosing with the facialis-mandibularis artery to form the mandibular artery as in *Ophiodon*, it bifurcates; the ventral branch passes through the above mentioned foramen to become the *mandibular artery* (fig. 35, Man.A.): while the dorsal branch passes along the inner surface of the preopercle, gives off a rather large opercular artery, and terminates in the pseudobranchial artery.

Jugular Veins (fig. 35, J.V.).—The jugulars and their branches are practically the same as in *Ophiodon*.

The first pair of *epibranchial arteries* (figs. 35 and 36; Epbr. A.$_{(1)}$) unite in forming the dorsal aorta, and the second pair, the cœliaco-mesentric; there is an opening into the aorta from the cœliaco-mesenteric artery, corresponding to the common chamber of *Ophiodon*, but the subclavians arise separately from the dorsal aorta, opposite the opening into the cœliaco-mesenteric.

Subclavian arteries.—Each subclavian (fig. 36, Sub.A.) after leaving the head kidney passes to the inner musculature of the corresponding pectoral fin. Here it separates into the subclavian artery proper, which is essentially the same as in *Ophiodon*, and a *hypobranchial artery*. This vessel (fig. 36: Hypobr.A.) passes ventrad a short distance, gives off a large branch, designated as the *posterior ventral artery* (fig. 36; Ven.A.$_{(1)}$) which passes ventro-caudad, supplying the ventral fin musculature and terminates in the right and left ventral fin arteries. The main stem of the hypobranchial passes cephalad and ventrad, and together with the corresponding vessel from the opposite side anastomoses with the anterior ventral artery. On the left side the hypobranchial artery has no posterior ventral branch. The hypobranchial artery in *Anoplopoma* may not be homologous with the similar named vessel in *Ophiodon*, which is really a branch of the ventral artery and anastomoses with a branch of the subclavian.

Only one *subclavian venous trunk* (fig. 36: Sub.V.$_{(2)}$) was noticed. It arose from an external and an internal branch.

The outer subclavian vein penetrated the scapula with the corresponding artery and joined the internal subclavian vein in forming the common subclavian trunk, which terminates in its respective horn of the kidney.

The vessel designated as the *anterior ventral artery* (fig. 36; Ven.A.) arises from the ventral union of the second right and left efferent branchial arteries; principally, however, from the second left efferent branchial artery. After passing over the combined trunk of the third and fourth afferent branchial vessels it gives off the *pharynx artery*. This vessel (fig. 36; Phar.A.) supplies the pharynx region, and soon sends off the *coronary artery* (fig. 36; Cor.A), which passes along the dorsal side of the ventral aorta to the heart. In all other genera studied the pharynx artery arose directly from the second or the third efferent branchial arteries. The anterior ventral artery evidently corresponds to the ventral artery of the other species; except that it extends only to the origin of the pelvic arch. In addition to giving off the pharynx artery it sends off branches to the sterno-hyoideus muscle and anastomoses with the 2 hypobranchial arteries. It would be possible, however, in *Anoplopoma* for blood in the anterior ventral artery to reach the ventral fins by passing through the right hypobranchial artery into the posterior ventral artery. By the separation of the right hypobranchial from the subclavian we would have in the anterior ventral, right hypobranchial, and posterior ventral arteries an irregular shaped vessel corresponding somewhat to the ventral artery of the other genera.

As in *Sebastodes*, there is in addition to the main inferior jugular and left branch, a right inferior jugular, which drains the ventral branchial muscles from the right side and empties into the right precava.

Cœliaco-mesenteric Artery.—This trunk (fig. 37; Cœ.Mes.-A.) upon reaching the œsophagus separates into the cœliac and mesenteric arteries respectively. The *mesenteric artery* soon divides into intestinal artery$_{(1)}$ and a short stem from which the *right* and *left gastric arteries* have their source. The latter vessel (figs. 37 and 38; L.Gas.A.) makes a cephalic curve across the œsophagus and continues on the left side of the stomach to the apex: while the former (fig. 37: R.Gas.A.) crosses the corresponding vein and continues parallel with it along the right and dorsal side of the stomach to the apex. From the right gastric the *posterior gall-bladder artery* is given off to supply the posterior two thirds of the bladder, and a small branch is also given off to a gland-like body marked G. Intestinal artery$_{(1)}$ (fig. 37; Int.A.$_{(1)}$) crosses over the right portal and continues caudad to the right of intestinal vein$_{(1)}$. Directly in front of the spleen this artery divides into a dorsal and a ventral vessel. The dorsal artery (fig. 37, Int.A.$_{(1a)}$) passes to the right of the spleen, gives off the *splenic artery* (fig. 37; Spl.A.) to the spleen, and crossing the intestinal vessels$_{(2)}$ continues caudad along the posterior horn of the iliac loop; giving off numerous branches to the anterior horn and the posterior end of the intestine, and finally terminates on the dorsal side of the rectum. The ventral branch (fig. 37; Int.A.$_{(1b)}$) passes ventrad and to the left of the spleen. Opposite the spleen it sends off the *posterior gastric artery* (fig. 37; P.Gas.A.), which crosses the cæca behind the corresponding vein, and supplies the posterior or cardiac end of the stomach. The main ventral intestinal vessel continues along the lower side of the posterior end of the intestine and terminates on the ventral side of the rectum.

Immediately after leaving the main trunk the *cœliac artery* (fig. 37; Cœ.A.) gives off the *right hepatic artery* (figs. 37 and 38; R.Hep.A.), which after crossing the cœliac and right portal sends off branches along the radicals of the right portal to the right lobe of the liver, and also gives off the *anterior gall-bladder artery*, which supplies the anterior third of the bladder, and does not anastomose with the posterior gall-bladder artery. Passing beneath intestinal vessels$_{(1)}$ the cœliac artery gives off a rather large *left hepatic artery* (figs. 37 and 38; L.Hep.A.), which follows along in front of the left portal, giving off numerous branches to the left lobe of the liver, which penetrate the liver with the large radicals of the common portal; while none of the branches of the left hepatic anastomose with similar branches of the right hepatic, several of them send up branches that supply the ventral portion of the stomach. Shortly after the branching off of the left hepatic from the cœliac, intestinal artery$_{(2)}$ is given off to the right (fig. 37: Int.A.$_{(2)}$): passing caudad to the right of the corresponding vein it crosses under the ventral branches of intestinal vessels$_{(1)}$, the spleen, and the dorsal branches of intestinal vessels, and continuing caudad between the anterior and posterior horns of the iliac loop, supplies both of them. The cœliac artery proper separates into the *right* and *left pyloric cæca arteries*. The former (fig. 37: R.Cæ.A.) passes around the pylorus on pyloric cæcum$_{(3)}$, and bifurcates into a dorsal and a ventral branch: the ventral branch gives off a large branch which crosses under this cæcum, and continues caudad between cæcum$_{(1)}$ and cæcum$_{(2)}$, giving off branches to each. The *left pyloric cæca artery* (fig. 37: L.Cæ.A.) passes to the left of the pylorus between cæcum$_{(4)}$ and cæcum$_{(5)}$, giving off branches to each.

Portal System. — As in *Sebastodes* the 2 portals unite in forming a common portal, that breaks up into numerous radicals.

The *right portal* (fig. 37: R.Por.V.) has its origin from the right gastric, and intestinal vein$_{(1)}$. *Intestinal vein*$_{(1)}$ (fig. 37: Int.V.$_{(1)}$) arises from a dorsal and a ventral branch. The former (fig. 37: Int.V.$_{(1a)}$) arises from the dorsal side of the rectum, and runs cephalad, parallel to the corresponding artery, but below it: receiving branches from the posterior end of the intestine and anterior horn of the iliac loop, it crosses intestinal vessels$_{(2)}$ and passes above and to the right of the spleen from which it receives the *splenic vein* (fig. 37; Spl.V.). Directly in front of the spleen the dorsal intestinal vein receives the ventral intestinal branch (fig. 37; Int.V.$_{(1b)}$), which arises from the lower side of the rectum and passes forward along the ventral side of the corresponding artery. Curving around the ventral and left side of the spleen it receives two branches: the first one, which is the *posterior gastric vein* (fig. 37: P.Gas.V.) arises from the cardiac end of the stomach, and runs along in front of the posterior gastric artery; while the anterior vessel has its source from two branches, one coming from between pyloric cæca$_{(1) \text{ and } (2)}$, and the other from cæcum$_{(3)}$. After receiving these branches the ventral intestinal branch crosses over intestinal vessels$_{(2)}$, and in front of the spleen unites with the dorsal intestinal branch to form main *intestinal vein*$_{(1)}$, which shortly joins the *right gastric vein* (fig. 37; R.Gas.V.) to form the *right portal*. This trunk (fig. 37; R.Por.V.) passes under intestinal artery$_{(1)}$, and when the right lobe of the liver is reached, sends off a branch to it, and anastomoses with the left portal to form the common portal. The branch to the right lobe of the liver receives the *gall-bladder vein* (fig. 37; G.Bl.V.), which drains the entire bladder, and receives a branch from a gland-like body marked G.

The *left portal vein* (fig. 37; L.Por.V.) has its origin from intestinal vein$_{(2)}$ and two pyloric cæca veins. *Intestinal vein*$_{(2)}$ (fig. 37; Int.V.$_{(2)}$) arising from the iliac loop passes cephalad below the corresponding artery, and after crossing under the dorsal branch of intestinal vein$_{(1)}$, the spleen, and the ventral branch of intestinal vein$_{(1)}$ it receives a vessel coming from the dorsal surface of pyloric cæcum$_{(3)}$, designated as the *right pyloric cæca vein* (fig. 37; R.Cæ.V.), and later the *left pyloric cæca vein* (fig. 37; L.Cæ.V.), which arises from between the fourth and fifth pyloric cæca. The left portal thus formed curves around on the dorsal surface of the liver and anastomosing with the right portal forms the *common portal trunk* (fig. 38; C.Por.V.), which gives off several terminal branches or radicals to the liver. Into this common portal is poured a rather large *ventral gastric vein* (fig. 38; V.Gas.V.), which may to some extent take the place of the absent left gastric vein found in *Ophiodon*.

The *dorsal aorta* presents no peculiarities, except that there are a great number of *spermatic arteries* (fig. 37; Sper.A.), usually 9 or 10.

Renal Portal System.—In the kidney there is a complete renal portal system. The *caudal vein* (fig. 37; Cau.V.) runs along the left dorsal surface of the kidney as the renal portal vein, giving off large *afferent renal veins* (fig. 37; A.Ren.V.) to each side; while the much smaller *efferent renal veins* (fig. 37; E.Ren.V.) return the blood to the *right cardinal*. This trunk receives, directly, 9 or 10 *spermatic veins* (fig. 37; Sper.V.) from the reproductive organs. The *intercostal veins* (fig. 37; Intc.V.), however, do not empty directly into the cardinal, but reach it through the efferent renal veins.

From the previous description it would seem that the vascular system of *Anoplopoma* exhibits many points of resemblance to the more generalized Teleosts. The external carotid, hyoidean, subclavian, hypobranchial, and coronary trunks appear to have a more primitive arrangement than is even shown in *Sebastodes*.

IX. GENERAL CONSIDERATIONS AND SUMMARY.

Since it is almost impossible to determine whether certain variations in the blood vessels are primitive or secondary it is not the intention of this paper to draw any conclusions as regards the classification of this group on the basis of the circulatory system, until after the anatomy of the other systems has been worked up. Still it is thought, although perhaps not practicable, that the vascular system might be used in the classification of families and genera, but could not be used in the discrimination of species. In the genus *Sebastodes* a great number of species were studied, both generalized and specialized, but no more variation was noticed in different species than could be found among individuals of the same species.

Several interesting anastomoses were noticed in both the arterial and venous systems. In *Ophiodon* we have in the region of the nasal sac a union of a branch of the internal carotid with one of the external carotid. The hyoidean artery anastomoses with the main stem of the external carotid to form the mandibular artery. A branch of the ventral artery joined one of the subclavian in the pectoral fin canal. The anterior spinal artery, a branch of the subclavian, united in the neural canal with the myelonal artery, a branch of the internal carotid. Two gall-bladder arteries unite on the surface of the bladder. Usually the posterior mesenteric artery communicates with intestinal artery$_{(1)}$, and there are connecting arteries between the right pyloric caeca artery and intestinal artery$_{(1)}$. In *Sebastodes* the two anterior spermatic arteries unite with the posterior or spermatic artery proper. In Hexagrammos the two hepatic arteries anastomose. In *Anoplopoma* the hyoidean arteries anastomose with the pseudobranchial arteries, and the hypobranchial arteries unite with the anterior ventral artery. Among the veins in *Ophiodon* there is an anastomosis under the nasal sac of a branch of the internal jugular with one of the external jugular. A sinus-like vessel connects the two internal jugulars in the eye-muscle canal. A small vein connects the posterior encephalic veins directly behind the cerebellum. The ventral intercostal veins anastomose dorsally with the main intercostal veins. The gall-bladder veins unite on the surface of the bladder, and there are connecting vessels between the right pyloric cæca vein and intestinal vein$_{(1)}$. There is always some communication between the two portals: either they terminate in a common portal as is the case with *Sebastodes* and *Anoplopoma*, or terminal branch (a) of the left portal unites with the right portal as in *Hexagrammos*, or else there is a connecting vein in the neighborhood of the spleen as in *Ophiodon* and *Scorpænichthys*. If a posterior mesenteric vein is present as in *Ophiodon* and *Scorpænichthys* there is a grand anastomosis on the posterior or cardiac end of the stomach of branch Z of the posterior mesenteric with the right, left, and posterior gastric veins; and branch Y of the posterior mesenteric, usually, anastomoses with intestinal vein$_{(1)}$. The anterior spermatic veins in *Sebastodes* unite with the posterior or spermatic vein proper, and in *Scorpænichthys* the left gastric vein anastomoses with the ventral gastric vein.

In all the specimens studied there was the so-called choroid gland in the eye, a double vaso-ganglion or retia mirabilia, and a double retia mirabilia is also present in the air-bladder of *Sebastodes*.

The arrangement of the vascular and the blood vessels in the pseudobranchial filaments is essentially the same as in the branchial filaments, and it seems reasonable to suppose that the arterial blood for the eye receives additional oxygen in its course through the pseudobranchial capillaries.

Summary of the Arteries.—The carotids in all species studied, but *Anoplopoma*, rise from a common trunk, which soon separates into the external and internal carotids. In *Anoplopoma* each of the carotids rises directly from the first efferent branchial artery. In every case the internal carotid divides into the orbito-nasal and encephalic arteries. In all the genera but *Anoplopoma* the main stem of the external carotid unites with the hyoidean artery to form the mandibular artery, but in this genus the hyoidean artery branches in the region of the preopercle. The ventral fork passes through a foramen in front of the preopercle to become the mandibular artery: while the dorsal fork passes along the inner surface of the hyomandibular and anastomoses with the pseudobranchial artery. Usually the pseudobranchial artery has its origin from the main stem of the external carotid (facialis-mandibularis) in the facial region, but with *Anoplopoma* the pseudobranchial artery rises from the external carotid close to its origin from the first efferent branchial artery; in fact it might be said to rise with the external carotid from the first efferent branchial artery, being fully as large as the carotid. An ophthalmic or efferent pseudobranchial artery always rises from the efferent pseudobranchial arteries, which supplies only the choroid coat of the eye. In *Ophiodon* the ventral artery rises from the ventral union of the second and third pairs of efferent branchial arteries; while in the other genera it comes from the union of the second efferent vessels. This artery in *Anoplopoma* is a short vessel barely reaching the pelvic bones; the supply for the ventral fin region comes from the subclavian. In all the genera but *Anoplopoma*, the pharynx artery, from which the coronary rises, has its source directly from one of the second or third efferent branchial arteries, but in this genus it rises from the ventral artery. There is always a distinct circulus cephalicus formed by the union of the encephalic, internal carotid, common carotid, first efferent branchial, and the first epibranchial arteries. Both pairs of epibranchials terminate in a common chamber from which the dorsal aorta, cœliaco-mesenteric, and subclavians have their origin; in some cases, however, this chamber is simply an opening between the aorta and the cœliaco-mesenteric. The dorsal aorta is essentially the same in all the genera; passing caudad beneath the vertebral column it gives off the renal and spermatic arteries to the kidney and the reproductive organs, the neural, hæmal, and intercostal arteries to the body wall, and finally terminates in the caudal fin. The subclavian arteries are practically the same in all the forms studied: they may arise from a single trunk or separately as was described under *Ophiodon*, or they may arise from the dorsal aorta as in *Anoplopoma*. In the case of *Anoplopoma* a rather large hypobranchial artery is given off, which anastomoses with the anterior ventral artery, and the right hypobranchial sends off the posterior ventral artery for the ventral fin region. The cœliac artery always supplies the pyloric cæca. With *Ophiodon*, *Sebastodes*, and *Anoplopoma* it is the source of the left hepatic artery, and in *Ophiodon*, *Hexagrammos*, and *Anoplopoma* it gives off intestinal artery$_{(2)}$. From the mesenteric artery, intestinal artery$_{(1)}$, the splenic and 2 gastric arteries have their origin. In *Hexagrammos* and *Scorpænichthys* the right gastric is the source of the left hepatic artery, and in *Sebastodes* it is the source of the right spermatic and the anterior air-bladder arteries, the left spermatic artery coming from the left gastric artery. In *Scorpænichthys* the entire intestinal supply comes from the mesenteric artery.

Summary of the Veins. — The jugular and its branches are essentially the same in all the species studied, receiving the mandibular, hyoidean, maxillary, orbito-nasal, ophthalmic, eye-muscle, and encephalic veins. In addition to the main inferior jugular and the left fork there are additional veins from the pharynx region in *Sebastodes*, *Scorpænichthys*, and *Anoplopoma*, which empty into the precava. Considerable variation is shown in the subclavian veins. There is always an external and an internal subclavian, and in *Scorpænichthys* there are several internal subclavians. Ordinarily the internal subclavian breaks up in the corresponding fork of the kidney, and the external subclavian empties into the precava, but in *Scorpænichthys* the external subclavian also breaks up in the kidney, while in *Anoplopoma* the external subclavian appears to penetrate the scapula foramen with the corresponding artery, uniting with the internal vein to form a common trunk, which breaks up in the kidney. Usually there are 2 ventral veins of equal size, but in *Ophiodon* one of them is often much the larger, draining the entire ventral fin region. There is always a distinct renal portal system. The caudal vein arises in the tail and passing forward in the hæmal canal below the aorta, receives the neural and hæmal veins, and upon entering the kidney, usually, bifurcates into the renal portal veins. With *Sebastodes* these veins extend much further cephalad than in the other genera, and in *Ophiodon* and *Scorpænichthys* the caudal vein receives the posterior mesenteric vein immediately after entering the kidney. It is of interest to note in connection with the posterior mesenteric vein, that in 2 other genera of the Cottoids, namely, *Calycilepidotus* and *Enophrys*, this vessel was absent. The right cardinal always arises in the caudal end of the kidney and drains the entire kidney, while the left cardinal drains only a portion of the left lobe of the kidney. The intercostal and the anterior neural veins break up in the kidney. The spermatic veins vary greatly in size, number, and position; with the female they arise from numerous branches, passing along the lateral surfaces of the ovaries; while in the male these branches come from the inside of the testes, and the spermatic veins terminate in the right cardinal or the renal portal veins. The cardinals and jugulars always unite on the ventral surface of their respective lobe of the kidney to form the precava, which pass around the œsophagus and terminate in the sinus venosus. There is always a distinctive hepatic portal system, which takes its origin from a right and a left portal vein. Usually the left portal vein has its source from 2 pyloric cæca veins, an intestinal, and a few ventral gastric veins. In *Scorpænichthys* it receives the entire intestinal supply. The right portal ordinarily arises from a right gastric, an intestinal, and a splenic vein: in *Scorpænichthys* no intestinal vein is received: while in *Sebastodes* the right gastric branch receives the additional anterior air-bladder vein. In *Ophiodon*, always, and in *Scorpænichthys*, usually, the 2 portals have no connection within the liver: while with *Hexagrammos* a branch of the left portal anastomoses with the right portal; and in *Sebastodes* and *Anoplopoma* the 2 portals and several minor vessels empty into and form a common portal. As in other vertebrates the portals break up into venous capillaries within the liver, and become collected by 2 hepatic veins, which unite in a hepatic sinus before emptying into the sinus venosus. An interesting vein in *Ophiodon* and *Scorpænichthys* is the left gastric vein, which arises from the left side of the stomach and empties directly into the precava. With the other genera this region is drained by enlarged ventral gastric veins, that empty into the left portal.

X. BRIEF SYNONYMY OF THE BLOOD VESSELS.

1. *Afferent branchial artery*, A.Br.A. Branches of the branchial artery, Monroe; Rameau (3), C. & V. Kiemenarterien, Hyrtl, Müller, and Stannius; Arterie branchiali, Emery; Arteria branchiales, McKenzie; Afferent branchial arteries, Parker; Kiemenarterien, V. & Y.[1]

2. *Afferent filament arteries*, A.Fil.A. Une branche (*n*) à chacun de ces feuillets, C. & V. Ast der Kiemenarterie, Müller; Desc. by Stannius; (*c*) fig. 318, Owen; Branches of the afferent artery, Parker; Desc. V. & Y.

3. *Afferent renal veins* or *Advehent renal veins*, A.Ren.V. Venæ renalis advehens, Stannius; Vena aveente renale, Emery; Vena renalis advehens, McKenzie; Afferent renal veins, Parker.

4. *Air-bladder retia mirabilia artery* or *Anterior air-bladder artery*, A.Bl.A. Desc. Stannius; Branch of cœliac to air-bladder, Owen; Desc. and fig. Emery; Desc. McKenzie; Artery to rete mirabile, Parker; Arterie der Schwimmblase, V. & Y.

5. *Air-bladder retia mirabilia vein* or *Anterior air-bladder vein*, A.Bl.V. Desc. Stannius; fig. Emery; Vessels from rete mirabile, Parker; Schwimmblasenvene, V. & Y.

6. *Auricle*, Aur. Oreillete, C. & V. Vorkammer, Müller, Stannius, and V. & Y. Auricle, Owen and Parker; Atrio, Emery; Atrium, McKenzie.

7. *Bulbus arteriosus*, B.Art. Bulbe (γ), C. & V. Bulbo aortico, Emery; Bulbus arteriosus, Hyrtl, Müller, Stannius, Owen, McKenzie, Parker, and V. & Y.

8. *Caudal artery*, Cau.A. Caudal aorta, Hyrtl; Arteria caudalis, Müller, Stannius, and McKenzie; Caudal artery, Parker; Bauchaorta, V. & Y.

9. *Caudal vein*, Cau.V. Veins from the tail, Monroe; Vena caudalis, Hyrtl. Müller, and Stannius; Vena cardinalis, Owen;

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[1] Abbreviations C. & V. stand for Cuvier and Valenciennes, V. & Y. for Vogt and Yung, and Desc. for described.

Vena codale, Emery; Vena caudalis, McKenzie; Caudal vein, Parker.

10. *Cœliac artery*, Cœ.A. An artery like unto our cœliac, Monroe; Arteria cœliaca, Hyrtl and Stannius; Cœliac, Owen; A. Mesentertca inferiore Emery (?); Cœliac artery, Parker.

11. *Cœliaco-mesenteric artery*, Cœ.Mes.A. Arteria cœliaco-mesenterica, Hyrtl, Stannius, and McKenzie: Arteria cœliaca, Emery (?); La grande artère aux viscères (π), C. & V. Cœliaco-mesenteric artery, Owen; Cœliaco-mesenteric artery, Parker; Baucharterie, V. & Y.

12. *Common carotid arteries*, C.Car.A. Les artères de la tête (*s*), C. & V. Carotis communis, Stannius; Kopfarterien, V. & Y. Common carotid arteries, Parker.

13. *Coronary artery*, Cor.A. Coronary artery, Monroe; Fig. C. & V. Kranzarterie, Hyrtl and Müller: Coronary artery, McKenzie and Parker.

14. *Coronary veins*, Cor.V. Coronary veins, Monroe and Parker.

15. *Dorsal aorta*, D.Ao. Trunk of descending aorta, Monroe; Aorte, C. & V. Aorta, Hyrtl, Müller, Owen, Emery, V. & Y. Aorta decendens, McKenzie: Dorsal aorta, Parker.

16. *Efferent branchial arteries*, E.Br.A. Branchial veins, Monroe: La grande veine de la branchie (λ), C. & V. Kiemenvenen, Hyrtl, Müller, Stannius, and V. & Y. Vene branchiali, Emery; Venæ Branchiales, McKenzie; Efferent branchial arteries, Parker.

17. *Efferent filament arteries*, E.Fil.A. Une veine branchiale (*θ*), C. & V. Ast der Kiemenvene, Müller: Desc. Stannius: (d) fig. 318, Owen: Desc. McKenzie and V. & Y. Branches of the efferent arteries, Parker.

18. *Efferent renal veins* or *Revehent renal veins*, E.Ren.V. Venæ renales revehentes, Stannius: Vena reveente, Emery.

19. *Encephalic artery* or *Brain artery*, Enc.A. Zweige zum Hirn, Müller: Hirnarterie, Stannius: Encephalic arteries (3), McKenzie, Cerebral artery, Parker; Hirnarterie, V. & Y.

20. *Encephalic vein*, Enc.V. Desc. by Stannius; Desc. and fig. by Emery: Anterior cerebral vein, Parker.

21. *Epibranchial arteries*, Epbr.A. (μ), C. & V. Aortenwurzeln, Hyrtl: Venæ branchiales communes, Müller; Epibranchial arteries, Parker.

22. *External carotid arteries* or *posterior carotid arteries*, E.Car.A. Arteries sent to jaws, Monroe (?); Carotis externa, Hyrtl and McKenzie; Carotis posterior, Müller and Stannius; Carotids, Owen; Carotide posteriore, Emery; Posterior carotids, Parker; Gesichtsarterie and Arteria facialis, V. & Y.

23. *External jugular or facial veins*, Ex.J.V. Desc. by Stannius; Anterior facial veins, Parker; Gesichtsvene or Vena facialis, V. &. Y.

24. *Hæmal arteries*, Hae.A. Hæmal arteries, Owen and McKenzie; Fig. C. & V. and V. & Y.

25. *Hæmal veins*, Hae.V. Hæmal veins, Owen and McKenzie; Fig. C. & V. and V. & Y.

26. *Hepatic sinus*, Hep.S. and *Hepatic veins*, Hep.V. Venae cava Hepaticae, Monroe; Les venes du foie, C. & V. Lebervene, Müller and Stannius; Hepatic vein, Owen and McKenzie; Hepatic veins and sinus, Parker; Lebervene, V. & Y.

27. *Hyoidean artery*, Hyo.A. Fig. C. & V. Arteria hyoideo-opercularis, Müller; Arteria hyoidea, Stannius; Hyo-opercular artery, Owen; Arteria, ioidea, Emery; Hyoidean artery, Parker.

28. *Hyoidean vein*, Hyo.V. Vena ioidea, Emery; Hyoidean sinus, Parker (?).

29. *Hypobranchial artery*, Hypobr.A. Fig. by Monroe; Desc. by McKenzie; Hypobranchial artery, Parker.

30. *Inferior jugular vein*, I. J. V. External jugular vein, Monroe; Vena jugularis inferior, Müller, Stannius, and McKenzie; Inferior jugular vein, Parker.

31. *Inner iris vein*, I.Ir.V. Die innere Vene der Iris, Müller.

32. *Intercostal arteries*, Intc.A. Arteriæ intercostales, Hyrtl, Müller and Stannius; Intercostals, Owen and McKenzie; Intervertebrale æste V. & Y.

33. *Intercostal veins*, Intc.V. Venæ intercostales, Müller and McKenzie; Intercostal veins, Parker.

34. *Internal carotid artery*, I.Car.A. Retrograde artery (ζ), Monroe (?); Carotis anterior, Müller and Stannius; Carotis interna, Hyrtl and McKenzie; Carotide anteriore, Emery; Anterior carotid artery, Parker; Einen tieferen Stamm, V. & Y.

35. *Internal jugular veins*, In.J.V. Vena jugularis interna, Müller.

36. *Internal subclavian arteries*, I.Sub.A. Arteria branchialis, Stannius; Branchial artery, Parker.

37. *Intestinal artery* (1), Int.A. (1). Arteriæ intestinales mesenterica, Stannius; Posterior mesenteric artery, Owen; Mesenterica superiore, Emery (?); Mesenteric artery, McKenzie; Dorsal intestinal artery, Parker (?); Duodenalarterie, V. & Y. (?)

38. *Intestinal artery* (2), Int.A. (2). Fig. C. & V. Arteriæ intestinales cœliaco, Stannius; Ventral intestinal artery, Parker (?); Darmarterie, V. & Y. (?).

39. *Intestinal vein* (1), Int.V. (1). Darmvene, Müller; Desc. Stannius; Fig. Emery; Mesenteric vein, McKenzie; Dorsal intestinal vein, Parker (?); Darmvene, V. & Y. (?).

40. *Intestinal vein* (2), Int.V.(2). Ventral intestinal vein, Parker (?).

41. *Iris artery* or *Ophthalmic minor artery*, Ir.A. Arteria ophthalmica minor, Müller; Desc. Stannius.

42. *Iris vein* or *Ophthalmic minor vein*, Ir.V. Die äussere Vene der Iris, Müller; Die Vene der Iris, Stannius.

43. *Jugular vein*, J.V. Internal jugular vein, Monroe; Les veines de la tête (ω), C. & V.; Vena jugularis superior, Müller; Vena vertebralis anterior, Stannius; Vena jugularis, Owen; Vena giugulare, Emery; Anterior cardinals, McKenzie; Jugular vein, Parker; Jugularvene, V. & Y.

44. *Lateral arteries*, Lat.A. Arteria lateralis, Stannius; Lateral arteries, McKenzie.

45. *Lateral veins*, Lat.V. Lateral veins, McKenzie.

46. *Left cardinal vein*, L.Car.V. Abdominal or vena cava, Monroe; Les veines des reins (ψ), C. & V.; Vertebralvene, Müller; Vena vertebralis posterior, Stannius; Vena cardinalis, Owen; Vena cardinale, Emery; Left cardinal vein, McKenzie and Parker; Linke cardinalvene, V. & Y.

47. *Left gastric artery*, L.Gas.A. Fig. C. & V. and V. & Y. Anterior gastric artery, Parker (?).

48. *Left gastric vein*, L.Gas.V. Anterior gastric vein, Parker (?).

49. *Left hepatic artery*, L.Hep.A. Small artery resembling the hepatic artery, Monroe; Desc. by C. & V. and Müller; Arteriæ hepaticæ, Hyrtl and Stannius; Hepatic artery, McKenzie; Left hepatic artery, Parker; Leberarterie, V. & Y.

50. *Mesenteric artery*, Mes.A. An artery resembling our superior mesenteric artery, Monroe; Arteria mesenterica anterior, Hyrtl and Stannius; Arteria celiaca, Emery (?); Mesenteric artery, Parker; Baucharterie, V. & Y. (?).

51. *Myelonal artery*, My.A. Myelonal artery, Parker.

52. *Myelonal vein*, My.V. Not vena neuralis of Owen; Myelonal vein, Parker.

53. *Neural arteries*, Neu.A. Arteria spinales, Hyrtl; Neural arteries, McKenzie; Spinal arteries, Parker.

54. *Neural veins*, Neu.V. Neural veins, Owen and McKenzie; Spinal veins, Parker.

55. *Nutrient branchial arteries*, N.Br.A. Nutrient branchial arteries, Parker.

56. *Nutrient branchial veins*, N.Br.A. Venæ nutritiæ der Kiemenbogen, Müller; Venæ nutritiæ, Stannius and Owen; Nutrient branchial veins, Parker.

57. *Nutrient filament arteries*, N.Fil.A. Bronchialarterien, Müller; Arteria bronchialis, Stannius; Arteriæ nutritiæ, Owen.

58. *Nutrient filament veins*, N.Fil.V. Bronchialvenen, Müller; Vena bronchiales, Stannius.

59. *Ophthalmic artery* or *Efferent pseudobranchial artery*, Oph.A. Arteria ophthalmica magna, Müller and Stannius; Ophthalmic artery, Owen; Desc. and Fig., Emery; Ophthalmica magna, McKenzie; Ophthalmic artery, Parker; Efferent pseudobranchial artery, Allis.

60. *Ophthalmic vein*, Oph.V. Vena ophthalmica magna, Müller and Stannius; Desc. and Fig. Emery.

61. *Optic* or *Retina artery*, Opt.A. Die Gefässe der Retina und der Hallenschen Gefässe, Müller; Arteria ottalmica, Emery (?); Optic artery, Allis.

62. *Orbito-nasal artery*, O.N.A. Zweige zu den Augenmuskeln und zur Nase, Müller; Arteria etmoidale, Emery; Augenarterie, V. & Y.

63. *Orbito-nasal vein*, O.N.V. Vena etmoidale, Emery; Orbital sinus, Parker.

64. *Pharynx artery*, Phar.A. Pericardial artery, Parker (?).

65. *Posterior air-bladder artery*, P.A.Bl.A. Vena vescicale posteriore, Emery.

66. *Posterior encephalic vein*, P.Enc.V. Desc. by Emery; Posterior cerebral vein, Parker.

67. *Posterior* or *left portal vein*, L.Por.V. La veine porte (*λ*), C & V. Pfortaderstamm, Müller and Stannius; Portal trunk, Owen; Portal vein, McKenzie; Hepatic portal and Portal vein, Parker; Pfortader, V. & Y.

68. *Precaval vein* or *Ductus cuvieri*, Prec.V. Desc. and figured by Monroe; Trunci transversi, Stannius; Precaval vein, Owen; Tronco di Cuvier, Emery; Ductus cuvieri, McKenzie; Precaval vein, Parker; Ductus cuvieri, V. & Y.

69. *Pseudobranchial artery* or *Afferent pseudobranchial artery*, Ps.A. Part of Arteria hyoideo-opercularis, Müller; Part of Arteria hyoidea, Stannius; Part of Hyo-opercular, Owen; Part of Arteria ioidea, Emery; Pseudobranchial artery, Parker; Afferent pseudobranchial artery, Allis.

70. *Pyloric cæca arteries*, R.Cæ.A. Fig. C. & V. Desc. by Stannius, Parker, and V. & Y.

71. *Pyloric cæca veins*, R.Cæ.V. Fig. C. & V. Desc. by Stannius and V. & Y.

72. *Renal Arteries*, Ren.A. Arteria renales, McKenzie; Renal arteries, Parker; Nieren arterienzweige, V. & Y.

73. *Renal portal vein*, Ren.P.V. Vena renalis advehens, Stannius; Veine porte rénale, Jourdain; Vena aveente renale, Emery; Vena renalis advehens, McKenzie; Renal portal vein, Parker.

74. *Right cardinal vein*, R.Car.V. Vena vertebralis posterior dextra, Stannius: Venæ cardinales, Owen: Vena cardinale, Emery; Right cardinal vein, McKenzie and Parker; Rechte cardinalvene, V. & Y.

75. *Right gastric artery*, R.Gas.A. Desc. Müller, Stannius, and McKenzie: Gastric artery, Owen: Fig. and Desc. Emery: Dorsal gastric artery, Parker (?): Magenarterie, V. & Y.

76. *Right gastric vein*, R.Gas.V. Desc. Stannius: Fig. Emery: Gastric vein, McKenzie: Anterior lieno-gastric vein, Parker (?): Desc. and Fig. V. & Y.

77. *Right hepatic artery*, R.Hep.A. Einen für jeden Leberlappen, Müller; Arteriæ hepaticæ, Stannius, Right hepatic artery, Parker: Leberarterie, V. & Y.

78. *Sinus venosus*, Sin.Ven. Sinus veineux, C. & V. Sinus venosus, Stannius, Hyrtl, Owen, McKenzie, and Parker; Sinus communis, Müller; Venensinus, V. & Y.

79. *Spermatic artery*, Sper.A. Fig. C. & V. Genitalarterie, Müller and V. & Y. Desc. Stannius; Fig. Emery and C. & V. Genital artery, McKenzie: Spermatic artery, Parker.

80. *Spermatic vein*, Sper.V. Les veines des organes de la génération (ç), C. & V. Genitalvenen, Müller and V. & Y. Desc. Stannius; Fig. Emery; Genital veins, McKenzie; Spermatic veins, Parker.

81. *Splenic artery*, Spl.A. Fig. C. & V. and Emery; Desc. Stannius and Owen; Splenic artery, McKenzie and Parker; Desc. and Fig. by V. & Y.

82. *Splenic vein*, Spl.V. Fig. C. & V. and Emery; Desc. Stannius; Vein from spleen, Owen; Splenic vein, McKenzie and Parker; Desc. and Fig. V. & Y.

83. *Subclavian artery*, Sub.A. Subclavian artery, Monroe, Owen, McKenzie, and Parker; Arteria subclavia, Müller, Hyrtl, and Stannius; Arterie ascellari, Emery; Schulterarterie, V. & Y.

84. *Subclavian veins* (1), (2), and (3), Sub.V. (1) to (3). Subclavian vein, Monroe and Parker; Vena subclavia, Stannius; Includes the branchial vein of Stannius and Parker; Schultervene, V. & Y.

85. *Thyroid artery*, Thyr.A. Thyroid artery, McKenzie.

86. *Urinary bladder artery* and *vein*, Ur.B.A. and Ur.B.V. Fig. C. & V. and V. & Y.

87. *Ventral aorta* or *Branchial artery*, V.Ao. Branchial artery, Monroe and Owen; L'artère branchiale (ε), C. & V. Arteria branchialis, Müller; Kiemenarterienstamm, Stannius; Cardiac aorta, Huxley; Truncus arteriosus, McKenzie; Tronco dell'aorta, Emery; Gemeinsame Kiemenarterie, V. & Y.

88. *Ventral artery*, Ven.A. Ramus epigastricus decendens, Müller (?); Arteria epigastrica, Stannius; Fig. C. & V. Artery supplying the pelvic fins, Parker.

89. *Ventral intercostal arteries*, V.Intc.A. Fig. C. & V. Arteriæ intercostales ventrales, Müller.

90. *Ventral intercostal veins*, V.Intc.V. Fig. C. & V. Vena intercostales ventrales, Müller.

91. *Ventral veins*, Ven.V. May be homologous to the epigastric veins of Müller and Stannius.

92. *Ventricle*, Ven. Ventricule, C. & V. Herzkammer, Müller, Stannius, and V. & Y. Ventricolo, Emery; Ventricle, Owen, McKenzie, and Parker.

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XII. EXPLANATION OF THE PLATES.

All figures were drawn from actual dissections. Fig. 1 was compiled from the dissections of three or four specimens, the others from a single specimen.

The arteries are colored red and the veins blue. A vessel drawn in dotted lines signifies that it passes in or behind a bone, muscle, or organ.

PLATE I.

Ophiodon elongatus; Blue cod.

FIG. 1. Represents a general lateral view of the vascular system. The hyoid vessels are cut and the arch moved caudad from its natural position to show the deeper branchial vessels, and a considerable part of the caudal portion of the body between the vent and the caudal fin is left out.

2. Dorsal view of an injected gill or branchial filament. Meshes of the capillary network are diagrammatic and are greatly enlarged. Injected with Hoyer's chrome yellow gelatin mass. Natural size.

3. Dorsal view of a pseudobranchial filament. Efferent vessels in yellow. Its network is also greatly enlarged. Injected as Fig. 2. Natural size.

4. Lateral view of a portion of the efferent pseudobranchial filament artery. Injected as Fig. 2. Leitz 3. Oc. 1. × ½.

5. Represents a ventral view of the union of the efferent branchial arteries to form the main arterial trunks, and also the large veinous trunks emptying into the precaval veins. Only the left dorsal branchial retractor muscle is indicated. A 15 lb. *Ophiodon*, × ½.

6. A portion of the viscera from the left and dorsal side. Opposite side of the stomach shown from Fig. 1. 40 lb. *Ophiodon*. × ¼.

7. Origin of the caudal vein from the ventral side, showing its relations with the lymphatic system. 15 lb. *Ophiodon*, × ½.

8. Deeper dissection of Fig. 7. showing the ending of the caudal artery.

9. Anterior view of a caudal vertebra, showing the caudal trunks in section. 15 lb. *Ophiodon*, × ½.

10. General lateral view of the blood supply to the kidney, testes, and urinary-bladder of a 15 lb. *Ophioden*, × ½.

11. Dorsal dissection of the liver to show the main trunks. Portal system in blue and hepatic system drawn in outline. 20 lb. *Ophiodon*, × ½.

PLATE I

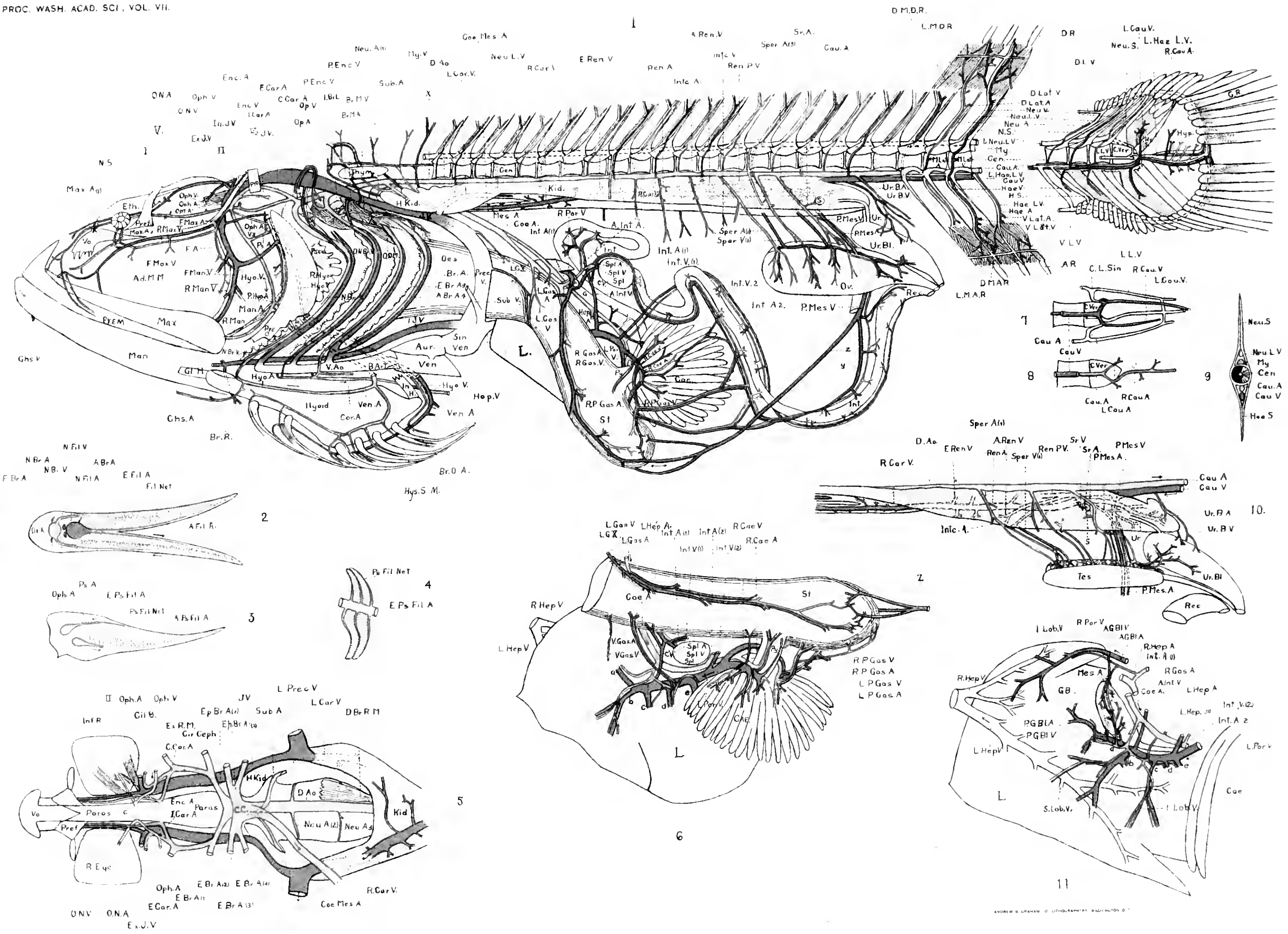

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PLATE II.

Ophiodon elongatus; Blue cod.

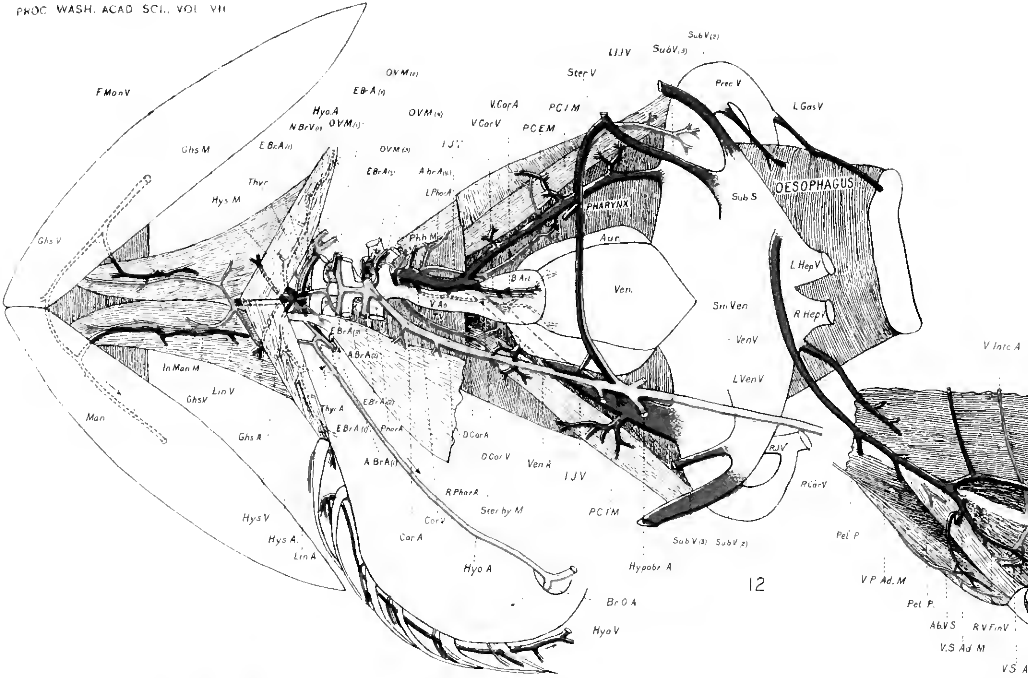
Fig. 12. Represents a general ventral view of the head region, including the ventral or pelvic fins. Hyoid arch and genio-hyoideus muscle entirely removed from the left side. Pectorals also not shown. 40 lb. *Ophiodon*, × ½.

13. Eye muscles from the left side. 15 lb. *Ophiodon*, × ½.

14. Shows the blood supply to the inner surface of the right pectoral fin. 40 lb. *Ophiodon*, × ½.

15. Represents a doral dissection at the level of the floor of the brain case. To show the blood supply for the eye, eye muscles, and brain. Floor of the brain case removed, and the trigeminal-facialis trunks are shown on the right side. 20 lb. *Ophiodon*, × ½.

16. General lateral view in the region of the left head kidney. To show the blood supply for the posterior part of the brain and the cord. × ½.



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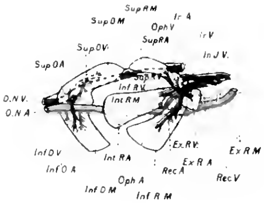

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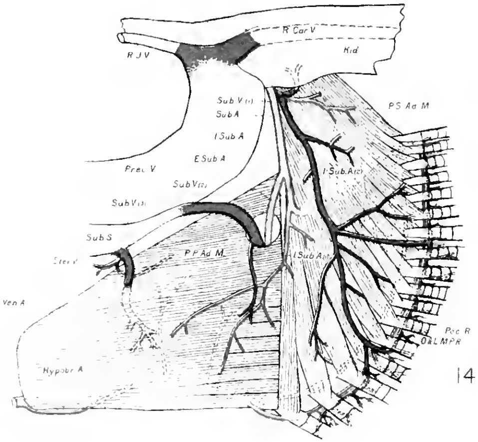

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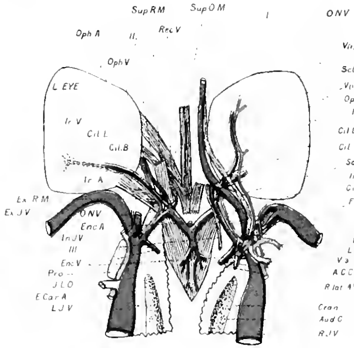

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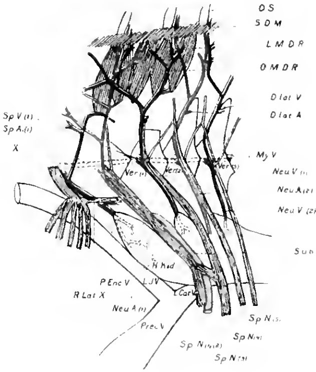

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PLATE III.

Ophiodon elongatus; Blue cod.

Hydrolagus colliei; Chimæra (Fig. 26).

FIG. 17. Represents the blood supply to and from the nasal sac, as seen from the right side. Anterior part of the eye shown in outline. 40 lb. *Ophiodon*, × 2.

18. Same as 17. Nasal sac in outline, to show the veins leaving the inner side of the sac.

19. Dissection of the right eye from the inside. The sclerotic coat and silver layer of the choroid are removed to show the large choroid sinus, the double rete mirabile or choroid gland, and the iris vein, all of which run in the vascular layer of the choroid coat. 20 lb. *Ophiodon*, natural size.

20. Same eye, but deeper dissection to show the choroid artery and its rete mirabile.

21. Frontal section through the retina and choroid coats, showing the choroid artery, the choroid sinus, and the retina artery in section. 20 lb. *Ophiodon*, natural size.

22. Shows an inside view of the right eye. A sagittal incision was made nearly through an injected eye and the three coats were folded to the right. The entire course of the retina artery from its entrance with the optic nerve until it ends on the lens is distinctly shown. 15 lb. *Ophiodon*, × ½.

23. General lateral view of the blood supply to and from the brain. 15 lb. *Ophiodon*, natural size.

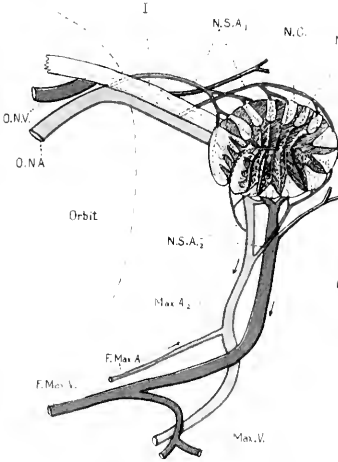
23*a*. Blood vessels to and from the auditory organs. 30 lb. *Ophiodon*, natural size.

24. General dorsal view of the vascular supply of the same brain as Fig. 23. Cranial nerves and anterior encephalic veins shown only on the right side.

25. Same brain as above from the ventral side. Cranial nerves not shown on the right side.

26. General lateral view of the main branchial vessels of *Hydrolagus colliei*, Chimæra. Inserted to show the wide variation in the carotid arteries. × ½.

PLATE III



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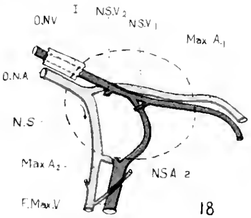

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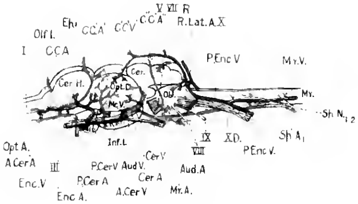

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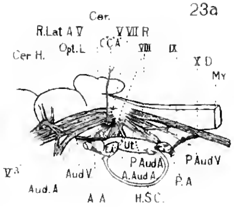

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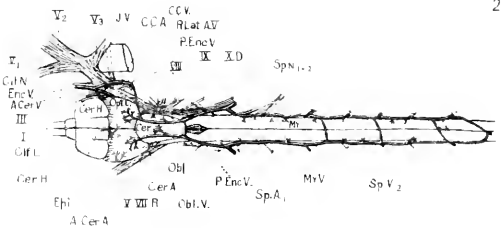

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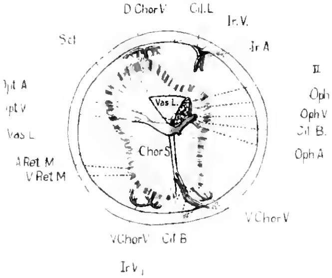

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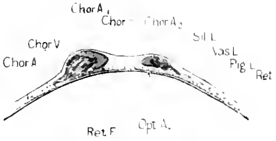

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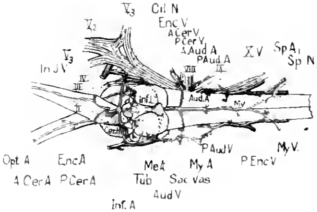

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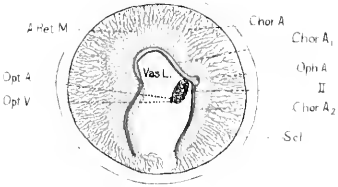

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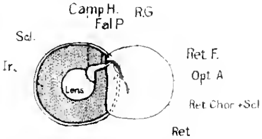

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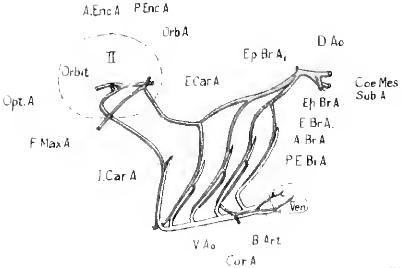

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PLATE IV.

Hexagrammos decagrammus; Sea trout (Figs. 27 and 28).
Scorpænichthys marmoratus; Cabezon (Figs. 29 and 30).
Sebastodes auriculatus; Rock cod (Figs. 31 and 34).
Sebastodes flavidus; Rock cod (Figs. 32 and 33).

FIG. 27. Represents a general lateral view of the viscera of a 12 in. *Hexagrammos.* The organs are greatly spread out, in order to better display their blood vessels. × ½.

28. Same specimen as above, showing the opposite or left side of the stomach.

29. General lateral view of the viscera of a 15 in. *Scorpænichthys.* The organs are well spread out to show their blood supply and the liver is not figured. × ½.

30. Same specimen as above, showing the left or opposite side of the stomach, and including the liver and the inner surface of the left pectoral fin. Hepatic system shown in dotted lines.

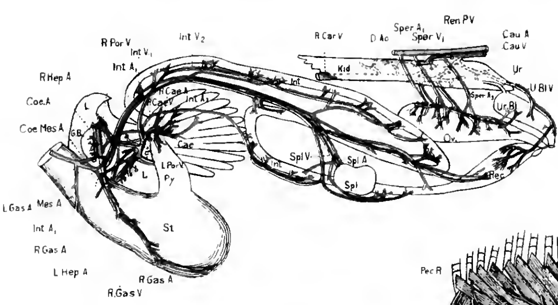
31. Represents a general lateral view of the viscera of a 12 in. *Sebastodes auriculatus.* Body tilted to show the ventral surface of the kidney, and all the organs spread out so as to best reveal their blood vessels. Notice the spermatic vein emptying directly into the left precaval vein. × ½.

32. A portion of the viscera, showing the blood supply for the left side of the stomach (opposite side from Fig. 31), and the liver of a 10 in. *Sebastodes flavidus.* This species, though one of the most generalized of the genus, has a system of blood vessels identical with *S. auriculatus*, which is one of the most specialized. × ½.

33. Shows the blood supply to the gall-bladder and to a gland-like body. *Sebastodes flavidus*, × ½.

34. Shows a variation in the vascular system to the gall-bladder. *Sebastodes auriculatus*, × ½.

27



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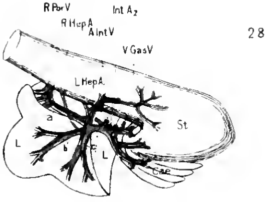

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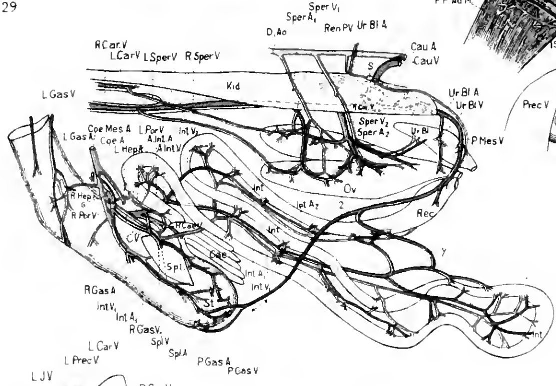

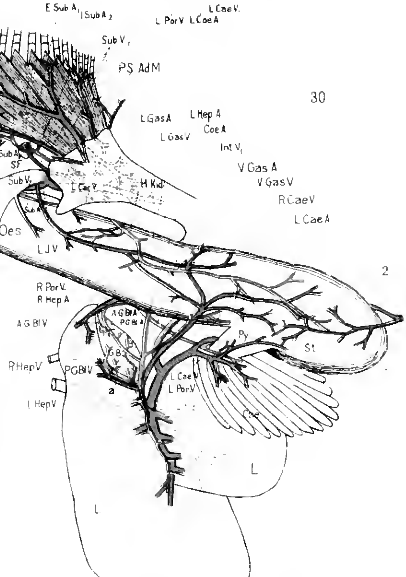

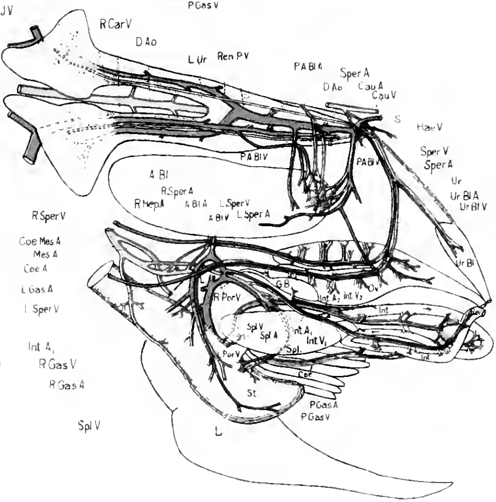

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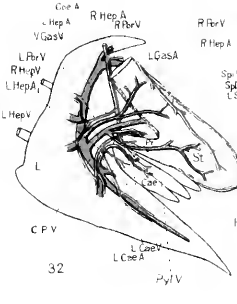

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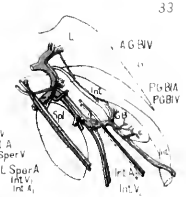

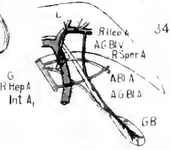

34

H
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Se
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FIG.

Proc. Wash. Acad. Sci., June, 1905.

PLATE V.

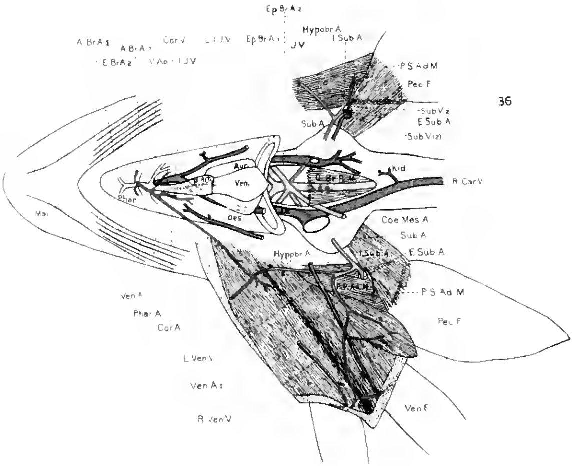
Anoplopoma fimbria; Black cod.

FIG. 35. Represents general lateral view of the principal trunks in the head region of *Anoplopoma*, × ½.

36. Shows general ventral view of the head region, including the pectoral and ventral fins of *Anoplopoma*. Ventral musculature and œsophagus removed to show the heart and union of the epibranchial arteries to form the dorsal aorta, cœliaco-mesenteric, and subclavian arteries. × ½.

37. View of the viscera of *Anoplopoma* from the left and dorsal side. × ½.

38. A portion of the viscera of *Anoplopoma* from the left and ventral side. ½.



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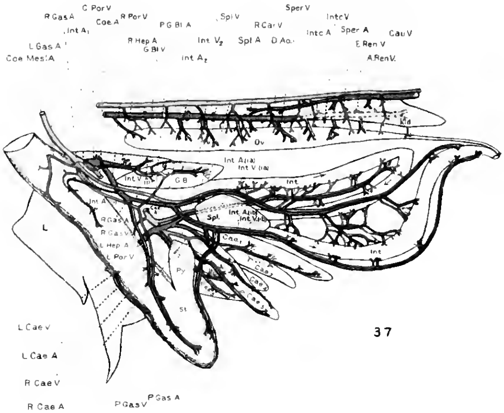

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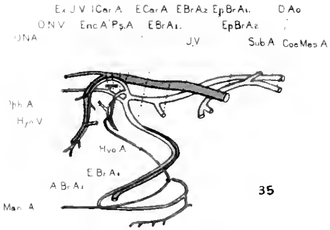

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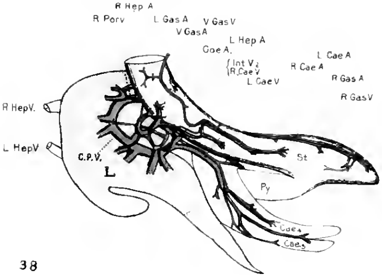

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PLATE VI.

Heart of Ophiodon elongatus.

FIG. 39 is from a photograph of the posterior half of a large *Ophiodon's* heart, looking inward and caudad. This heart had previously been injected with a gelatin mass and hardened in formalin, and the cut was made directly between the anterior and posterior auriculo-ventricular valves. × 4.

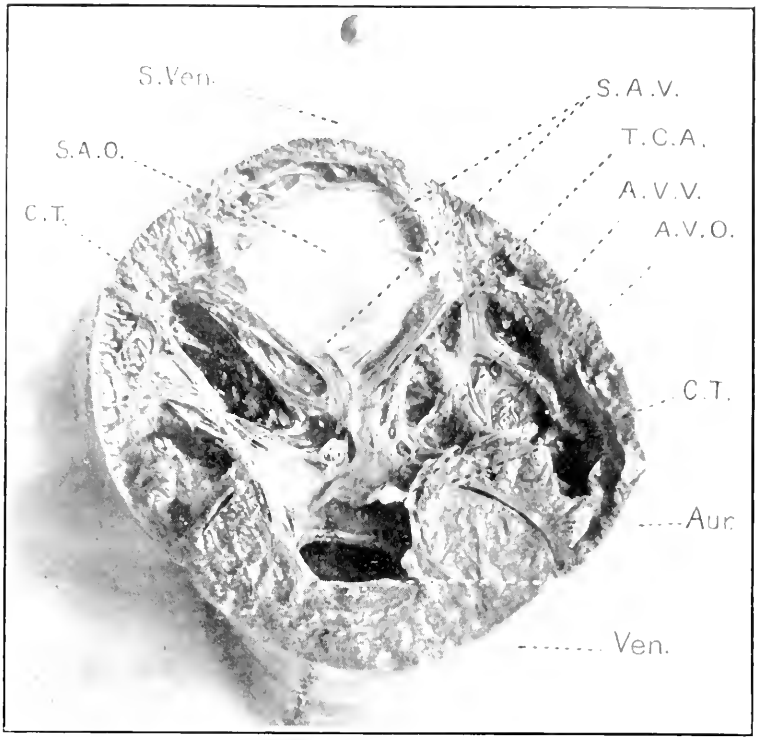
40. As above, is a photograph of the ventral side of a large *Ophiodon's* heart. A portion of the ventral wall of the ventricle had been removed to the depth of the central cavity to show the semi-lunar and auriculo-ventricular valves. × 2.

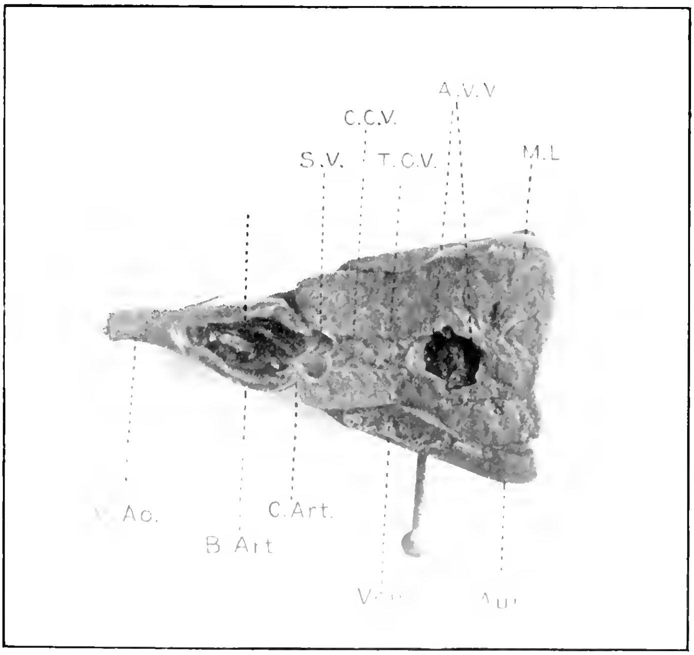
Abbreviations used. — Aur., Auricle. A.V.O., Auriculo-ventricular opening. A.V.V., Auriculo-ventricular valves. B.Art., Bulbus arteriosus. C.Art., Conus arteriosus. C.C.V., Central cavity of the ventricle. C.T., Connective tissue. L.F., Longitudinal folds or ridges. M.L., Muscular layer. S.A.O., Sinu-auricular opening. S.A.V., Sinu-auricular valves. S.V., Semi-lunar valves. S.Ven., Sinus venosus. T.C.A., Trabeculæ carnæ auricle. T.C.V., Trabeculæ carnæ ventricle. V.Ao., Ventral aorta. Ven., Ventricle.

Text-fig. 1. — Represents a transverse section through the auricle and ventricle of *Ophiodon elongatus.* This section was made through one of the auriculo-ventricular valves. Camera lucida. Leitz No. 2 obj. with lower lens removed.

Text-fig. 2. — Camera drawing of transverse section through the region of the conus arteriosus. Same obj. as above.

Abbreviations used. — Aur., Auricle. A.V.V., Auriculo-ventricular valve. C.T., Connective tissue. E.M.F., Elastic muscle fibers. End., Endothelium. L.M., Longitudinal muscle fibers. S.V., Semi-lunar valves. T.M., Transverse muscle fibers. Ven., Ventricle.


S.Ven.
S.A.V.
T.C.A.
S.A.O.
A.V.V.
C.T.
A.V.O.
C.T.
Aur.
Ven.


A.V.V
C.C.V.
S.V.
T.C.V.
M.L
V. Ao.
C.Art.
B.Art
Ven.
Aur

XIII. REFERENCE LETTERS AND ABBREVIATIONS USED IN THE FIGURES.

The letter D or V prefixed to an abbreviation indicates dorsal or ventral; R or L, right or left; A or P, anterior or posterior; Ex or In, external or internal. A series of similar named vessels is numbered from cephalad to caudad.

A.A.	Anterior ampulla.
A.Aud.A.	Anterior auditory artery.
a to e.	Terminal branches or radicals of the left portal.
A.Bl.	Air-bladder.
A.Bl.A.	Anterior air-bladder or retia mirabilia artery.
A.Bl.V.	Anterior air-bladder or retia mirabilia vein.
A.Br.A.	Afferent branchial arteries.
Ab.V.S.	Abductor muscle of ventral spine.
A.Cer.A.	Anterior cerebral artery.
A.Cer.V.	Anterior cerebral vein.
Ad.Hym.[1]	Adductor hyomandibularis.
Ad.M.M.	Adductor mandibulæ muscles.
Ad.Pal.A.	Adductor palatine arch. M. adductor arcus palatini.
A.Fil.A.	Afferent filament arteries.
A.G.Bl.A.	Anterior gall-bladder artery.
A.G.Bl.V.	Anterior gall-bladder vein.
A.Int.A.	Anterior intestinal artery.
A.Int.V.	Anterior intestinal vein.
A.Ps.Fil.A.	Afferent pseudobranchial filament artery.
A.R.	Anal fin rays.
A.Ren.V.	Afferent or advehent renal veins.
A.Ret.M.	Arterial retia mirabilia of choroid gland.
Aud.A.	Auditory artery.
Aud.C.	Auditory capsule.
Aud.V.	Auditory vein.
Aur.	Auricle.
B.Art.	Bulbus arteriosus.
Br.A.	Branchial arches.
Br.M.A.	Dorsal branchial muscle arteries.
Br.O.A.	Branchiostegal arteries.
Br.R.	Branchiostegal rays.
Cæ.	Pyloric cæca.
Cæ$_{(1)\text{ to }(5)}$	Five pyloric cæca of *Anoplopoma*.
Camp.H.	Campanula Halleri.
Cau.A.	Caudal artery.
Cau.V.	Caudal vein.
C.C.A.	Cranial cavity arteries.
C′.C′.A′.	
C″.C″.A″.	
C.Car.A.	Common carotid artery.
C.C.V.	Cranial cavity veins.
C′.C′.V′.	
Cen.	Centrum.

Cer.	Cerebellum.
Cer.A.	Cerebellum artery.
Cer.H.	Cerebral lobes or hemispheres.
Chor.	Choroid coat of the eye.
Chor.A	Choroid arteries.
Chor.A.$_{(1)}$	Superior choroid artery.
Chor.A.$_{(2)}$	Inferior choroid artery.
Chor.S.	Choroid sinus.
Chor.V.	Choroid veins.
Cil.B.	Ramus ciliaris brevis.
Cil.L.	Ramus ciliaris longus.
Cil.N.	Ciliary nerve.
C.L.Sin.	Caudal lymphatic sinus.
Cœ.A.	Cœliac artery.
Cœ.Mes.A.	Cœliaco-mesenteric artery.
Con.Art.	Conus arteriosus.
Cor.A.	Coronary artery.
Cor.V.	Coronary vein.
C.P.V.	Common portal vein. *Sebastodes* and *Anoplopoma* only.
C.R.	Caudal fin rays.
Cran.	Cranial wall.
C.′V.′	Connecting vein. *Ophiodon* and *Scorpænichthys* only.
C.Ver.	Caudal vertebra.
D.Ao.	Dorsal aorta.
D.Br.R.M.	Dorsal branchial retractor muscle. Retractor arc. branch dorsalis of Vetter.
D.Chor.V.	Dorsal choroid vein.
Di.Op.M.	Dilator opercular muscle.
D.Lat.A.	Dorsal lateral arteries.
D.Lat.V.	Dorsal lateral veins.
D. & L.M.P.R.	Depressor and levator muscles of the pectoral rays.
D.L.V.	Dorsal lymphatic vessel.
D.M.A.R.	Depressor muscle, anal ray.
D.M.D.R.	Depressor muscle, dorsal ray.
D.O.M.	Dorsal oblique muscles of the branchial arches (3). Obliqui dorsales of Vetter.
D.R.	Dorsal fin rays.
D.S.	Dorsal spines.
E.A.	External ampulla.
E.Br.A.	Efferent branchial arteries.
E.Br.L.	External branchial levator muscles (4). Levatores arch. branch externi of Vetter.
E.Car.A.	External carotid artery.
E.Fil.A.	Efferent filament arteries.
Enc.A.	Encephalic artery.
Enc.V.	Encephalic vein.
Epbr.A.	Epibranchial arteries.
Epi.	Epiphysis.
E.Ps.Fil.A.	Efferent pseudobranchial filament arteries.

E.Ren.A.	Efferent renal or revehent renal veins.
E.Sub.A.	External subclavian artery.
Eth.	Ethmoid.
Ex.J.V.	External jugular vein.
Ex.R.A.	External rectus artery.
Ex.R.M.	External rectus muscle.
Ex.R.V.	External rectus vein.
F.A.	Facial artery.
Fal.P.	Falciform process.
Fil.Net.	Branchial filament network.
F.Man.A.	Facialis-mandibularis artery.
F.Man.V.	Facialis-mandibularis vein.
F.Max.A.	Facialis-maxillaris artery.
F.Max.V.	Facialis-maxillaris vein.
G.	Gland.
G.B.	Gall-bladder.
Ghs.A.	Geniohyoideus artery.
Ghs.M.	Geniohyoideus muscle.
Ghs.V.	Geniohyoideus vein.
Gl.H.	Glossohyal.
H.	Hypophysis.
Hæ.A.	Hæmal arteries.
Hæ.L.V.	Hæmal lymphatic vessels.
Hæ.V.	Hæmal veins.
Hep.S.	Hepatic sinus.
Hep.V.	Hepatic vein.
H.Kid.	Head kidney.
H.S.	Hæmal spine.
H.S.C.	Horizontal or external semicircular canal.
Hyo.A.	Hyoidean artery.
Hyoid.	Hyoid arch.
Hyo.V.	Hyoidean vein.
Hyp.	Hypural bone.
Hypobr.A.	Hypobranchial artery.
Hys.A.	Hyohyoideus inferior artery.
Hys.M.	Hyohyoideus inferior muscle.
Hys.S.M.	Hyohyoideus superior muscle.
Hys.V.	Hyohyoideus inferior vein.
I.Br.L.	Internal branchial levator muscles (2). Levatores arcuum branchialium interni of Vetter.
I.Car.A.	Internal carotid artery.
I.Ir.V.	Inner iris vein.
I.J.V.	Inferior jugular vein.
I.lob.V.	Interlobular veins.
Inf.A.	Infundibular artery.
Inf.L.	Hypoaria or inferior lobes.
Inf.O.A.	Inferior oblique muscle artery.
Inf.O.M.	Inferior oblique muscle.
Inf.O.V.	Inferior oblique muscle vein.

Inf.R.M.	Inferior rectus muscle.
In.H.	Interhyal.
In.J.V.	Internal jugular vein.
In.Man.M.	Intermandibularis muscle.
Int.	Intestine.
Int.A.$_{(1)}$.	Intestinal artery$_{(1)}$.
Int.A.$_{(1a)}$.	Dorsal branch of intestinal artery$_{(1)}$. In *Anoplopoma*.
Int.A.$_{(1b)}$.	Ventral branch of intestinal artery$_{(1)}$. In *Anoplopoma*.
Int.A.$_{(2)}$.	Intestinal artery$_{(2)}$.
Intc.A.	Intercostal arteries.
Intc.V.	Intercostal veins.
Int.R.A.	Internal rectus artery.
Int.R.M.	Internal rectus muscle.
Int.R.V.	Internal rectus vein.
Int.V.$_{(1)}$.	Intestinal vein$_{(1)}$.
Int.V.$_{(1a)}$.	Dorsal branch of intestinal vein$_{(1)}$. In *Anoplopoma*.
Int.V.$_{(1b)}$.	Ventral branch of intestinal vein$_{(1)}$. In *Anoplopoma*.
Int.V.$_{(2)}$.	Intestinal vein$_{(2)}$.
Ir.	Iris.
Ir.A.	Iris artery.
Ir.V.	Iris vein.
Ir.V.$_{(1)}$.	Ventral or minor iris vein.
I.Sub.A.	Internal subclavian artery.
I.Sub.A.$_{(1)}$.	Superficial branch of the internal subclavian artery.
I.Sub.A.$_{(2)}$.	Profundus branch of the internal subclavian artery.
J.L.O.	Jugular lymphatic opening.
J.V.	Jugular vein.
Kid.	Kidney.
L.	Liver.
Lat.A.	Lateral arteries.
Lat.V.	Lateral veins.
L.Cæ.A.	Left pyloric cæca artery.
L.Cæ.V.	Left pyloric cæca vein.
L.Car.V.	Left cardinal vein.
L.Cau.A.	Left caudal artery.
L.Cau.V.	Left caudal vein.
L.Gas.A.	Left gastric artery.
L.Gas.V.	Left gastric vein.
L.G.X.	Left gastric ramus of the vagus.
L.Hæ.L.V.	Longitudinal hæmal lymphatic vessel.
L.Hep.A.	Left hepatic artery.
L.Hep.A.$_{(1)}$.	Posterior or minor left hepatic artery.
L.Hep.V.	Left hepatic vein.
Lin.A.	Lingual artery.
Lin.V.	Lingual vein.
L.L.V.	Lateral lymphatic vessel.
L.M.A.R.	Levator muscles of the anal rays.
L.M.D.R.	Levator muscles of the dorsal rays.
L.Neu.L.V.	Longitudinal neural lymphatic vessel.

L.Op.M.	Levator opercular muscle.
L.Pal.A.	Levator palatine arch. Levator arcus palatini of Vetter.
L.Pal.A.A.	Levator of palatine arch artery.
L.P.Gas.A.	Left posterior gastric artery.
L.P.Gas.V.	Left posterior gastric vein.
L.Por.V.	Left portal vein.
L.Sper.A.	Left spermatic artery. In *Sebastodes*.
L.Sper.V.	Left spermatic vein. In *Sebastodes* and *Scorpænichthys*.
L.Ven.V.	Left ventral vein.
L.V.Fin.A.	Left ventral fin artery.
L.V.Fin.V.	Left ventral fin vein.
Man.	Mandible (Dentary, articular, and angular bones).
Man.A.	Mandibular artery.
Man.V.	Mandibular vein.
Max.	Maxilla.
Max.A.(1).	Anterior or maxillary artery.
Max.A.(2).	Posterior maxillary artery.
Max.V.	Maxillary vein.
Me.A.	Mesencephalic artery.
Mes.A.	Mesenteric artery.
Me.V.	Mesencephalic vein.
M.Lat.A.	Median lateral arteries.
M.Lat.V.	Median lateral veins.
My.	Myelon, myel, or spinal cord.
My.A.	Myelonal artery.
My.V.	Myelonal vein.
N.Br.A.	Nutrient branchial arteries.
N.Br.V.	Nutrient branchial veins.
Neu.A.	Neural arteries.
Neu.L.V.	Neural lymphatic vessels.
Neu.V.	Neural veins.
N.Fil.A.	Nutrient branchial filament artery.
N.Fil.V.	Nutrient branchial filament vein.
N.S.	Nasal sac.
N.′S.′	Neural spines.
N.S.A.	Nasal sac arteries.
N.S.V.(1).	Anterior nasal sac vein.
N.S.V.(2).	Posterior nasal sac vein.
Obl.	Oblongata or medulla oblongata.
Obl.V.	Oblongata vein.
Oc.Cl.V.	Occipito-clavicularis muscle.
O.D.M.	Obliqui dorsales muscles.
Oes.	Oesophagus.
Olf.L.	Olfactory lobes or bulbs.
O.N.A.	Orbito-nasal artery.
O.N.V.	Orbito-nasal vein.
Op.A.	Opercular artery.
Oph.A.	Ophthalmic artery.
Oph.V.	Ophthalmic vein.

Opt.A.	Optic or retina artery.
Opt.L.	Optic lobes.
Opt.V.	Optic or retina vein.
Op.V.	Opercular vein.
Orb.A.	Orbital artery. In *Hydrolagus*.
Ov.	Ovaries.
O.V.M.	Obliqui ventrales muscles.
P.A.	Posterior ampulla.
P.A.Bl.A.	Posterior air-bladder artery.
P.A.Bl.V.	Posterior air-bladder vein.
Paras.	Parasphenoid.
P.Aud.A.	Posterior auditory artery.
P.And.V.	Posterior auditory vein.
P.C.E.M.	Pharyngo-clavicularis externus muscle.
P.Cer.A.	Posterior cerebral artery.
P.Cer.V.	Posterior cerebral vein.
P.C.I.M.	Pharyngo-clavicularis internus muscle.
P.E.Br.A.	Posterior efferent branchial arteries. In *Hydrolagus*.
Pec.F.	Pectoral fin.
Pel.	Pelvic arch.
Pel.P.	Ventral process of the pelvic arch.
P.Enc.V.	Posterior encephalic vein.
P.Gas.A.	Posterior gastric artery.
P.Gas.V.	Posterior gastric vein.
P.G.Bl.A.	Posterior gall-bladder artery.
P.G.Bl.V.	Posterior gall-bladder vein.
Phar.A.	Pharynx artery.
Ph.H.M.	Pharyngo-hyoideus muscle.
P.Hyo.A.	Posterior hyoidean artery.
Pig.L.	Pigment layer of the choroid coat.
P.Mes.A.	Posterior mesenteric artery.
P.Mes.V.	Posterior mesenteric vein.
P.P.Ad.M.	Pectoral profundus adductor muscle.
Prec.V.	Precaval vein or Ductus Cuvieri.
Pref.	Prefrontal.
Prem.	Premaxilla.
Preo.	Preopercular.
Pro.	Prootic process.
Ps.A.	Pseudobranchial artery.
P.S.Ad.M.	Pectoral superficialis adductor muscle.
Pseu.	Pseudobranchia.
Ps.Fil.Net.	Pseudobranchial filament capillary network.
Py.	Pylorus.
Pyl.A.	Pyloric artery.
Pyl.V.	Pyloric vein.
R.Cæ.A.	Right pyloric cæca artery.
R.Cæ.V.	Right pyloric cæca vein.
R.Car.V.	Right cardinal vein.
R.Cau.A.	Right caudal artery.

R.Cau.V.	Right caudal vein.
Rec.	Rectum.
Rec.A.	Rectus artery.
Rec.V.	Rectus vein.
Ren.A.	Renal arteries.
Ren.P.V.	Renal portal vein.
Ret.	Retina.
Ret.F.	Retina fissure.
R.G.	Gland-like body in retina fissure.
R Gas.A.	Right gastric artery.
R.Gas.V.	Right gastric vein.
R.Hep.A.	Right hepatic artery.
R.Hep.V.	Right hepatic vein.
R.Hyo.	Ramus hyoideus.
R.Lat.X.	Ramus lateralis vagi.
R.Lat.A.V.	Facialis portion of the ramus lateralis accessorius.
R.Lat.A.X.	Vagus portion of the ramus lateralis accessorius.
R.Man.	Ramus mandibularis VII.
R.Man.V.	Ramus mandibularis trigemini or ramus maxillaris inferior trigemini.
R.Max.V.	Ramus maxillaris trigemini or ramus maxillaris superior trigemini.
R.P.Gas.A.	Right posterior gastric artery.
R.P.Gas.V.	Right posterior gastric vein.
R.Por.V.	Right portal vein.
R.Sper.A.	Right spermatic artery. In *Sebastodes*.
R.Sper.V.	Right spermatic vein. In *Sebastodes* and *Scorpænichthys*.
R.Ven.V.	Right ventral vein.
R.V.Fin.A.	Right ventral fin artery.
R.V.Fin.V.	Right ventral fin vein.
S.	Suprarenal bodies.
Sac.Vas.	Saccus vasculosus.
Scl.	Sclerotic coat.
Scl.A.	Sclerotic artery.
Scl.Ir.A.	Sclerotic-iris artery.
Scl.V.	Sclerotic vein.
S.D.M.	Superficial dorsal fin muscles.
S.F.	Scapula foramen.
Sil.L.	Silver layer of choroid coat.
Sin.Ven.	Sinus venosus.
S.Lob.V.	Sublobular veins.
Sp.A.	Spinal or myelon arteries.
Sper.A.	Spermatic arteries.
Sper.V.	Spermatic veins.
Spl.	Spleen.
Spl.A.	Splenic artery.
Spl.V.	Splenic vein.
Sp.V.	Spinal or myelon veins.
Sr.A.	Suprarenal artery.

Sr.V.	Suprarenal vein.
St.	Stomach.
Ster.hy.M.	Sternohyoideus muscle.
Ster.A.	Sternohyoideus arteries.
Ster.V.	Sternohyoideus veins.
Sub.A.	Subclavian artery.
Sub.S.	Subclavian sinus.
Sub.V.$_{(1)}$.	Internal subclavian vein.
Sub.V.$_{(2)}$.	External subclavian vein.
Sub.V.$_{(3)}$.	Minor external subclavian vein. In *Ophiodon*.
Sup.O.A.	Superior oblique muscle artery.
Sup.O.M.	Superior oblique muscle.
Sup.O.V.	Superior oblique muscle vein.
Sup.R.A.	Superior rectus muscle artery.
Sup.R.M.	Superior rectus muscle.
Sup.R.V.	Superior rectus muscle vein.
Tes.	Testes.
Thym.	Thymus gland.
Thyr.	Thyroid gland.
Thyr.A.	Thyroid artery.
Trap.M.	Trapezius muscle.
Tub.	Tuber (cinereum).
T.V.	Transversus ventralis muscle.
Ur.	Ureters.
Ur.Bl.A.	Urinary bladder artery. (Ur.B.A., in *Ophiodon*.)
Ur.Bl.	Urinary bladder.
Ur.Bl.V.	Urinary bladder vein. (Ur.B.V., in *Ophiodon*.)
Ur.S.	Urostyle.
Ut.	Utriculus.
V.Ao.	Ventral aorta.
Vas.L.	Vascular layer of the choroid coat.
V.Chor.V.	Ventral choroid vein.
Ven.	Ventricle.
Ven.A.	Ventral artery.
Ven.A.$_{(1)}$.	Posterior ventral artery. In *Anoplopoma*.
Ven.F.	Ventral or pelvic fins.
Ver.	Vertebra.
V.Gas.A.	Ventral gastric arteries.
V.Gas.V.	Ventral gastric veins.
V.Intc.A.	Ventral intercostal arteries.
V.Intc.V.	Ventral intercostal veins.
V.Lat.A.	Ventral lateral arteries.
V.Lat.V.	Ventral lateral veins.
V.L.V.	Ventral lymphatic vessel.
V.Myo.	Ventral myotomes.
Vo.	Vomer.
V.P.Ad.M.	Ventral or pelvic profundus adductor muscle. "Adductor profundus pelvis of McMurrich.
V.Ret.M.	Venous retia mirabilia of the choroid.

V.S.	Ventral spine.
V.S.Ad.M.	Ventral or pelvic superficialis adductor muscle. Adductor superficialis pelvis of McMurrich.
X.	Place for injecting the arteries.
Y.	Intestinal branch of posterior mesenteric vein.
Z.	Gastric branch of posterior mesenteric vein.
I.	Olfactory nerve.
II.	Optic nerve.
III.	Oculomotor nerve.
IV.	Pathetic or trochlear nerve.
V and VII.	Trigemino-facial complex.
VI.	Abducent nerve.
VIII.	Auditory nerve.
IX.	Glossopharyngeal nerve.
X.	Vagus or pneumogastric nerve.
$V_{(1)}$.	Truncus supra-orbitalis or ramus ophthalmicus superficialis V and ramus ophthalmicus superficialis VII.
$V_{(2)}$.	Truncus infra-orbitalis or buccalis-maxillo-mandibularis.
$V_{(3)}$.	Truncus hyomandibularis or hyoideo-mandibularis facialis.
V.VII.R.	Trigemino-facialis roots.
V.Scl.	Supra-orbital ramus to sclerotic coat.
X.D.	Dorsal root of the vagus.
X.V.	Ventral root of the vagus.

PROCEEDINGS

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THE GYMNOTIDÆ.

BY CARL H. EIGENMANN AND DAVID PERKINS WARD.

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THE Gymnotidæ are a family of fishes entirely confined to the fresh waters of tropical America. At least 4 species (*Sternarchus brasiliensis*, *Rhamphichthys marmoratus*, *Eigenmannia virescens* and *Giton fasciatus*) range as far south as the Rio de la Plata, the second having been taken at Rio Grande do Sul but not yet in the La Plata. The last three species range from the Orinoco south through the Amazon basin and the Paraguay basin; no species is represented in the coast-wise streams between Bahia and Rio Grande do Sul; and but one, *Giton fasciatus*, reaches Bahia. Four, *Sternarchus brasiliensis*, *Eigenmannia virescens*, *Giton fasciatus* and *Gymnotus carapus* have been found in the Rio San Francisco. But 2 species have representatives on the Pacific slope, *Eigenmannia humboldti*, which is found in the Magdalena basin and in the Mamoni, a stream emptying into the Pacific in Panama, and *Gymnotus æquilabiatus*, which is found in the Magdalena basin and about Guayaquil. North of Panama only a single species, *Giton fasciatus*, has been found. It has been recorded by Günther from the Rio Motagua. The same species is also found in the island of Trinidad and the islands of Grenada.

Several species are found in the Paraguay and Amazon rivers which have not been reported from as far south as the La Plata. These are *Hypopomus brevirostris* from the Cauca to Para and Paraguay, *Sternarchus albifrons* and *Gymnotus carapus* from the Orinoco through the entire course of the Amazons from Peru to Para and to Paraguay, and *Rhamphichthys reinhardti* which is not found north of the Amazons.

The place where more collections have been made than elsewhere and which must serve as an index of the abundance of the South American fish fauna is Manaos, or Barra do Rio Negro. At this place or in its neighborhood 12 of the 29 species have been taken; 21 species have been taken in the Amazons but not more than 14 in any one of its 3 sections. The accompanying geographical table will give an idea of the abundance of local faunas or the thoroughness with which collecting has been done. Fifty species have been described, of which 29 seem to be valid.

KEY TO THE GENERA OF GYMNOTIDÆ.

a. Caudal fin present; eye without free orbital margin; a large fontanel .... (*Sternarchinæ*.)

b. Snout not produced, the eye nearer tip of snout than to gill-opening.

c. Both jaws with teeth, those of the lower jaw in 2 series, those of the upper in 2 or more series.

d. Gape long, the angle of the mouth but little if any in front of eye; snout long.......................... *Sternarchus*, 1.

dd. Gape short, the angle of the mouth below the anterior or posterior nostrils; snout short.......... *Sternarchella*, 2.

cc. Upper jaw without teeth, those of the lower jaw in a single series; snout very short................. *Sternarchogiton*,[1] 3.

bb. Snout produced, the eye nearer the gill-opening than to tip of snout; anal long.

c. Snout straight, the gape moderate..... *Sternarchorhamphus*, 4.

cc. Snout strongly decurved; mouth minute, the gape about twice length of eye.......................... *Sternarchorhynchus*, 5.

aa. No caudual fin, the tail ending in a point.

f. A large fontanel; vent below the head.

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[1] If Peter's description of *Sternarchus sachsi* is correct and *sachsi* does not contain teeth in either jaw, it should stand as the type of a new genus.

g. Snout produced into a long tube; no teeth; vent below or in advance of eyes; anal fin beginning at throat; eye nearer gill-opening than end of snout............*Rhamphichthys*, 6.

gg. Snout not produced into a long tube.

h. No teeth; vent behind eyes; anal beginning below pectoral; eye nearer tip of snout than gill-opening, minute.

i. Mental region without adipose filament.....*Hypopomus*, 7.

ii. Mental region with a filament of adipose tissue in a groove along each side..... ....*Steatogenys*, 8.

hh. Teeth present in both jaws.

j. Eye without a free orbital margin; jaws equal or the upper the longer; teeth feeble, in a patch or band; anal beginning below or in front of pectoral; snout more or less compressed, conical; eye large.
Eigenmannia, 9.

jj. Eye small, with a free orbital margin; teeth feeble, in bands; jaws equal or the upper the longer; gill-opening small; anal beginning below pectoral or slightly in front of it; vent in front of gill-opening; snout blunt, conical............ ....*Gymnotus*, 10.

ff. No fontanel; maxillary very small; lower jaw projecting; teeth rather strong, in a single series in each jaw; anal beginning behind pectoral; vent below gill-opening; gill-opening comparatively large; head depressed in front; eye small.
Giton, 11.

1. **Sternarchus** Bloch & Schneider. (Figs. 1–3.)

Sternarchus Bloch & Schneider, 497, tab. 94. (Type: *Gymnotus albifrons* L.)

Sternarchus Cuvier, Règne Animal, II, 237, 1817 (*albifrons*).

Apteronotus Lacépède, II, 208 (*passan* = *albifrons*).

Geographical distribution of the species: Amazons; Rio San Francisco, Paraguay and Parana.

a. Scales small, a maximum of 16 rows between lateral line and middle line of back.[1]

b. A maximum of 11 to 16 scales between lateral line and middle of back; angle of mouth in front of eye: snout 2.25 in head; depth of snout just in front of eye less than length of snout; depth of head more than 1.5 in its length......*brasiliensis*, 1.

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[1] Not examined in *S. bonapartii*.

bb. A maximum of 11 to 13 scales between lateral line and middle line of back; angle of mouth just below or a trifle in front of eye; snout about 2.5 in head; depth of snout just in front of eye equaling or exceeding length of snout; depth of head about 1.25 in its length ....*albifrons*, 2.

bbb. Angle of mouth behind eye; vent in front of eye; A. 165. (Castelnau)..*bonapartii*, 3.

aa. Scales large, a maximum of 6 scales between lateral line and middle line of back....................................*macrolepis*, 4.

1. STERNARCHUS BRASILIENSIS Reinhardt.

Sternarchus brasiliensis Reinhardt, Vidensk. Meddel. Naturh. Foren. Kjöbenh., 1852, or Wiegm. Arch. 1854, 182; Günther, Cat., VIII, 3, 1870 (Rio das Velhas) Lütken, Velhas Flodens Fiske, 247 and XIX, 1875 (Rio das Velhas); Steindachner, Flussf. Südam., III, 14, 1881 (Rio das Velhas); Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 61 (Rio das Velhas).

Sternarchus albifrons, Eigenmann & Norris, Revista Museu Paulista, IV, 349, 1900 (Piracicaba); not of Linnæus.

Habitat: Southeastern Brazil but not in its coastwise streams.

2. STERNARCHUS ALBIFRONS (Linnæus).

Gymnotus albifrons Linnæus, Syst. Nat., ed. XII, 1, 428, 1766; Pallas, Spic. Zool., VII, 36, tab. 6, fig. 1, 1769; Bonnaterre, Tabl. encycl. des trois régnes natura, Poiss., 37, pl. 24; fig. 82, m. 3, 1788.

Sternarchus albifrons, Bloch & Schneider, 497, tab. 94; Castelnau, Anim. Amer. Süd, Poiss., 91, pl. 45, fig. 1, 1855; Kaup. Apodes, 126; Steindachner, Sb. Akad. Wiss. Wien, LVIII, 1868, 249 (Cuyaba). Günther, Cat., VIII, 2, 1870 (Para; Santarem); Peters, Mb. Akad. Wiss. Berl., 1877, 473 (Apuré); Cope, Proc. Am. Philos. Soc. 1878, (Peruvian Amazon); Boulenger, Proc. Zool. Soc. 1887, 282, (Canelos); Steindachner, Flussf. Südam., III, 13, pl. 5, fig. 6, 1881 (Manacapuru: Teffe; Obidos); Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 61; Perugia, Ann. Mus. Civics Stor. Nat. Genova, ser. 2, vol. 4, 55, 1891 (Asuncion); Boulenger, Trans. Zool. Soc., XIV, 1896

37 (Descalvados); Boulenger, Boll. Torino, XIII, 1898 (Rio Zamora, Equador); Eigenmann & Kennedy, Proc. Acad. Nat. Sci. Phila. 1903, 30 (Arroyo Trementina).

Apteronotus passan Lacépède, Hist. Nat. Poiss., II, 209, pl. 6, fig. 3, 1800.

Sternarchus lacepedii Castelnau, Anim. Amer. Sud, Poiss., 93, pl. 45, fig. 3, 1855, **Surinam**.

Sternarchus maximilliani Castelnau, 93, pl. 45, fig. 4, 1855, **Urubamba**.

Habitat: Orinoco, Amazons and Paraguay.

3. STERNARCHUS BONAPARTII Castelnau.

Sternarchus bonapartii Castelnau, Anim. Amer. Sud, Poiss., 92, pl. 45, fig. 2, 1855, **Amazon**; Kaup, Apod., 126, 1856; Günther, Cat., VIII, 3, 1870; Cope, Proc. Am. Philos. Soc. 1878, 682 (Peruvian Amazon); Steindachner, Flussf. Südam., II, 42, 1881 (Manacapuru); Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 62.

Habitat: Amazons.

4. STERNARCHUS MACROLEPIS Steindachner.

Sternarchus macrolepis Steindachner, Flussf. Südam., III, 14, pl. V, fig. 7, 1881, **near Barra do Rio Negro and Lake Manacapuru**; Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 62; Boulenger, Trans. Zool. Soc., XIV, 427, 1898 (Rio Jurua).

Habitat: Amazon near mouth of Rio Negro and Jurua.

2. **Sternarchella** Eigenmann, new genus. (Fig. 4.)

Type: *Sternarchus schotti* Steindachner.

A glance at the figures of the species of *Sternarchus* and the type of this genus will show conclusively that *schotti* is not congeneric with *Sternarchus albifrons*. The snout is much shorter and the mouth is very much smaller.

Geographical distribution of the species: Barra do Rio Negro to Peru.

a. Gape moderate, angle of mouth below posterior nostril; A. 163; teeth of premaxillary and mandible in 2 series; opercle pointed;

snout 3.4 in head; depth of snout in front of eye much less than its length; depth of head 1.4 in its length. (Steindachner) *schotti*, 5.

aa. Gape short, angle of mouth below anterior nostril; A. 171; only 9 transverse scales below dorsal; lower jaw large, projecting beyond upper both anteriorly and laterally; eye much nearer tip of snout than gill-opening; depth equaling length of head, 8.5 in the length. (Cope) ....*balænops*, 6.

5. STERNARCHELLA SCHOTTI (Steindachner).

Sternarchus schotti Steindachner, Die Gymnotidæ, 4, pl. I, figs. 1 and 2, 1868, **Barra do Rio Negro**; Günther, Cat., VIII, 3, 1870; Cope, Proc. Am. Philos. Soc. 1878, 682 (Peruvian Amazon); Steindachner, Flussf. Südam., II, 42, pl. 2, fig. 2, 1881 (Manacapuru); Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 62.

Habitat: Amazons, from the Barra do Rio Negro to Peru.

6. STERNARCHELLA BALÆNOPS (Cope).

Sternarchus balænops Cope, Proc. Am. Philos. Soc. 1878, 682 **Peruvian Amazon**; Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 62.

Habitat: Peruvian Amazon.

3. **Sternarchogiton** Eigenmann, new genus. (Fig. 5.)

Type: *Sternarchus nattereri* Steindachner.

Steindachner in his original description recognized that *S. nattereri* represents a distinct group of Sternarchoid fishes. It is sufficiently distinguished by the absence of teeth in the upper jaw. (*Sternarchus* and γείτων, neighbor.)

Geographical distribution of the species: Orinoco to Barra do Rio Negro.

a. Lower jaw with a single series of teeth; head 12; depth 8; snout 3.5 in the head; A. 197; anus below eye; snout very short and convex. (Steindachner) ....*nattereri*, 7.

aa. Lower jaw without teeth; A. 168; head 10.5; depth 13.3; snout pointed; eye 3 in snout; lower jaw projecting; anterior nares in middle of length of snout, the posterior close to eye. (Peters) *sachsi*, 8.

7. STERNARCHOGITON NATTERERI (Steindachner).

Sternarchus nattereri Steindachner, Die Gymnotidæ, 3, pl. II, fig. 1, 1888, **Barra do Rio Negro**: Günther, Cat., VIII, 3, 1870; Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 62; Boulenger, Trans. Zool. Soc., XIV, 427, 1898 (Rio Jurua)
Habitat: Barra do Rio Negro and Jurua.

8. STERNARCHOGITON SACHSI (Peters).

Sternarchus sachsi Peters, Mb. Akad. Wiss. Berl. 1877, 473, **Apuré**: Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 62.
Habitat: Orinoco.

4. **Sternarchorhamphus** Eigenmann, new genus.

(Figs. 6 and 7.)

Type: *Sternarchus mulleri* Steindachner.

This genus is intermediate between *Sternarchus* and *Sternarchorhynchus*, having the long snout of the latter and the mouth in size approaching the former.

Geographical distribution of the species: Amazon at Para and in Peru.

a. Snout nearly or quite straight, the gape wide, more than half length of snout; eye midway between pectoral and tip of snout; mandible with a series of fine teeth on each side; depth 2.5 in head; A. 202. (Günther)..........................*macrostomus*, 9.

aa. Snout nearly straight, the gape moderate, $\frac{1}{4}$ length of snout; depth of head 1.6 in its length; 3 rows of slender teeth in lower jaw, 2 rows of smaller teeth in upper jaw; eye minute; depth less than length of head, 11 to 12 in total length. (Steindachner)..*mulleri*, 10.

aaa. Snout straight; gape very small, not more than $\frac{1}{10}$ of the length of the snout; depth of head about $\frac{1}{3}$ of its length; eye extremely minute, about midway between pectoral and tip of snout; several rows of minute teeth; depth of body $\frac{1}{2}$ the length of the head; a very strongly developed adipose fin along entire length; vent under chin. A. 220, originating a little in advance of gill-opening; lat. line 85. (Boulenger) *tamandua*, 11.

9. STERNARCHORHAMPUS MACROSTOMUS (Günther).

Sternarchus macrostomus Günther, Cat., VIII, 4, 1870, **Xeberos.**

Rhamphosternarchus macrostomus, Cope, Proc. Am. Philos. Soc. 1878, 682 (Peruvian Amazon).

Sternarchorhynchus macrostomus, Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 62.

Habitat: Peruvian Amazon.

10. STERNARCHORHAMPHUS MULLERI (Steindachner).

Sternarchus (*Rhamphosternarchus*) *mulleri* Steindachner, Flussf. Südam., III, 15, pl. V, fig. 4, 1881, **Para.**

Sternarchorhynchus mulleri, Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 62.

Habitat: Para.

11. STERNARCHORHAMPHUS TAMANDUA (Boulenger).

Sternarchus tamandua Boulenger, Trans. Zool. Soc., XIV, 427, plate XLII, 1898, **Rio Jurua,** tributary of the Amazon.

Habitat: Rio Jurua.

This species may represent a genus distinct from *Sternarchorhamphus* as here understood.

5. **Sternarchorhynchus** Castelanu. (Figs. 9 and 10).

Sternarchorhynchus Castelnau, 1856. Type: *Sternarchorhynchus mulleri* Castelnau = *oxyrhynchus*. Gill, Proc. Ac. Nat. Sci. Phila. 1864, 152.

Rhamphosternarchus Günther, Cat., VIII, 4, 1870 (*oxyrhynchus*).

Rhamphosternarchus Günther is synonymous with *Sternarchorhynchus* Castelnau. It includes the species with a caudal and long tubular snout and minute mouth.

Geographical distribution of the species: Marabitanos, Guiana and upper Amazon.

a. Anal with more than 200 rays.

b. Anal 210 to 226; mouth oblique; depth 1.6 to 1.75 in head. *mormyrus*, 12.

bb. Anal 205 to 215; mouth terminal; depth 2 in head.
oxyrhynchus, 13.
aa. Anal 185 to 188; snout much bent downward, its width at its middle 8 in its length; distance between eye and pectoral 1.5 in snout; depth 1.6 in head. (Boulenger)....*curvirostris*, 14.

12. STERNARCHORHYNCHUS MORMYRUS (Steindachner).

Sternarchus mormyrus Steindachner, Die Gymnotidæ, 5, pl. I, fig. 3, **Marabitanos**; Günther, Cat., VIII, 4, 1870 (Peruvian Amazon); Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 62.

Habitat: Marabitanos; Peruvian Amazon.

13. STERNARCHORHYNCHUS OXYRHYNCHUS (Müller & Troschel).

Sternarchus oxyrhynchus Müller & Troschel, Horæ Ichthyol., III, 16, pl. II, figs. 1 and 2, 1849, **Essequibo**; Kaup, Apod., 127; Günther, Cat., VIII, 4, 1870 (British Guiana); Boulenger, Trans. Zool. Soc., XIV, 427, 1898 (Rio Jurua).

Sternarchorhynchus oxyrhynchus, Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 62.

Sternarchorhynchus mulleri, Castelnau, Anim. Amer. Sud. Poiss., 1855.

Habitat: Guiana and Rio Jurua.

14. STERNARCHORHYNCHUS CURVIROSTRIS (Boulenger).

Sternarchus (*Rhamphosternarchus*) *curvirostris* Boulenger, Proc. Zool. Soc. 1887, 282, pl. XXIV, **Canelos.**

Sternarchorhynchus curvirostris, Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1881, 62.

Habitat: Canelos.

6. **Rhamphichthys** Müller & Troschel. (Fig. 12.)

Rhamphichthys Müller & Troschel, Horæ Ichthyol., III, 15, 1849. (Type: *Gymnotus rostratus* L.)

Geographical distribution of the species: Orinoco and Guianas south to Rio de la Plata.[1]

a. Eye equidistant from tips of snout and pectoral; distance of center of eye from gill-opening 2 in length of snout; eye 13 to 19 in head; anus in front of eye; A. 390 to 515; depth about 1.2 in head; brownish, variously spotted and banded. *rostratus*, 15.

aa. Eye nearly equidistant from tip of snout and gill-opening; distance of center of eye from tip of opercle 1 to 1.28 in snout. *marmoratus*, 16.

aaa. Distance of eye from tip of opercle 1.5 in length of snout. *reinhardtii*, 17.

15. RHAMPHICHTHYS ROSTRATUS (Linnæus).

Seba, Thesaur, II, tab. 69, fig. 3, and III, 99, tab. 32, fig. 5.

Gymnotus Gronow, Mus. Ichthyol., no. 73, 1754; Gronow, Zoophyl., no. 167.

Gymnotus rostratus Linnæus, Syst. Nat., ed. XII, 1, 428, 1766; Gronow, Syst., ed. Gray, 22, 1854.

Carapus rostratus, Cuvier, Règne Animal, II, 237, 1817.

Rhamphichthys rostratus, Müller & Troschel, Horæ Ichthyol., III, 15, 1849 (Guiana); Günther, Cat., VIII, 5, 1870 (Surinam; Brit. Guiana); Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 62.

Gymnotus longirostratus Lacépède, Hist. Nat. Poiss., II, 178, 1800.

Rhamphichthys schomburgkii Kaup, Apod., 135, 10, 1856; Steindachner, Die Gymnotidæ, 10, 1868, **Rio Negro.**

Rhamphichthys schneideri Kaup, Apod., 136, fig. 11, 1856, **Cayenne.**

Habitat: Guianas to Amazon.

16. RHAMPHICHTHYS MARMORATUS Castelnau.

Rhamphichthys marmoratus Castelnau, Anim. Amer. Sud, Poiss., 86, pl. 46, fig. 2, 1855, **Uraguay**; Kaup, Apod., 132, fig. 7, 1856, Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 62; Eigenmann, Ann. N. Y. Ac. Sci., VII, 1894, 625 (Itaituba).

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[1] It seems quite probable that the "species" are simply different forms of a single variable species.

Rhamphichthys pantherinus Castelnau, Anim. Amer. Sud, Poiss., 86, pl. 46, fig. 3, 1855, **Lake near the Acayale**; Kaup, Apod., 131, fig. 6, 1856; Günther, Cat., VII, 5, 1870; Peters, Mb. Akad. Wiss. Berl. 1877, 473 (Apuré); Cope, Proc. Am. Philos. Soc. 1878, 682 (Peruvian Amazon); Steindachner, Fisch-f. Cauca and Guayaquil, 38, 1880 (Manacapuru; Matto Grosso; Surinam; Uraguay; La Plata; Para; Obidos; Xingu; Rio Negro; Ucayale). Perugia, Ann. Mus. Civico Stor. Nat. Genova, ser. 2, vol. X, 55, 1891 (Asuncion and Rio Maciel at Buenos Aires).

Rhamphichthys lineatus Castelnau, Anim. Amer. Sud, Poiss., 87, pl. 47, fig. 1, 1855, **Tributary of Ucayale**; Kaup, Apod., 130, fig. 5, 1856.

Gymnotus rostratus, Steindachner, die Gymnotidæ, 8, 1868, in part (Matto Grosso; Surinam); (not of Linnæus).

Habitat: Orinoco and Guianas south to Rio de la Plata.

17. RHAMPHICHTHYS REINHARDTII Kaup.

Gymnotus rostratus, Bloch & Schneider, 522, tab. 106, 1801; not of Linnæus.

Gymnotus rostratus, Steindachner, Die Gymnotidæ, 8, 1868 (Rio Negro); in part.

Rhamphichthys reinhardtii Kaup, Apod., 132, fig. 8, 1856; Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 62.

Rhamphichthys blochii Kaup, Apod., 133, fig. 9, 1856; Günther, Cat., VIII, 5, 1860 (Para); Steindachner, Fisch-f. Cauca and Guayaquil, 38, 1880 (Rio Negro; Manacapuru; Para); Boulenger, Trans. Zool. Soc., XIV, 1896, 38 (Paraguay); Boulenger, Trans. Zool. Soc., XIV, 428, 1898 (Rio Jurua).

Habitat: Guinas south to Paraguay.

7. **Hypopomus** Gill. (Fig. 13.)

Hypopomus Gill, Proc. Ac. Nat. Sci. Phila. 1864, 152.

Type: *Rhamphichthys mulleri* Kaup.

Brachyrhamphichthys Günther, Cat., VIII, 6 (*artedii*).

Geographical distribution of the species: Cauca and Guianas south to Paraguay.

a. Snout less than 3 in head; spotted........................*artedi*,* 18.
aa. Snout 3 or more in head; sides with cross-bands.
  b. Head slender, compressed, conic; upper profile straight; length of head equaling depth; eye about 2 in snout; A. 160 to 260. *brevirostris*, 19.

18. HYPOPOMUS ARTEDI (Kaup).

Seba, III, tab. 32, fig. 2.

Rhamphichthys artedi Kaup, Apod., 128, 1856, **Mona**; Günther, Cat., VIII, 6, 1870.

Brachyrhamphichthys artedi, Eigenmann & Eigenmann, Proc. U. S. Nat Mus., XIV, 1891, 62.

Rhamphichthys mulleri Kaup, Apod., 129, 1856, **French Guiana**; Günther, Cat., VIII, 6, 1870.

Hypopomus mulleri, Gill, Proc. Ac. Nat. Sci. Phila. 1864, 152.

Brachyrhamphichthys mulleri, Eigenmann & Eigenmann, Proc. U. S. Nat Mus., XIV, 1891, 62.

Habitat: French Guiana.

19. HYPOPOMUS BREVIROSTRIS (Steindachner).

Rhamphichthys brevirostris Steindachner, Die Gymnotidæ, 6, pl. II, fig. 2; 1868, **Guaporé**; Günther, Cat., VIII, 6, 1870; Steindachner, Fisch-f. Cauca and Guayaquil, 37, 1880 (Santarem; Cauca, Rio Guapore), Perugia, Ann. Mus. Civico Storia Nat. Genova, ser. 2, vol. X, 56, 1891 (Central Chaco); Boulenger, Trans. Zool. Soc., XIV, 1896, 38 (Descalvados).

Brachyrhamphichthys brevirostris, Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 62; Eigenmann, Ann. N. Y. Ac. Sci., VII, 1894, 625 (Lower Amazon and Itaituba on the Tocantins).

Hypopomus brevirostris, Eigenmann & Kennedy, Proc. Ac. Nat. Sci. Phila. 1903, 530 (Campo Grande; Arroyo Chagalalina).

Habitat: Cauca, Amazon and tributaries, Paraguay.

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* The nominal species *artedi* and *mulleri* are distinguished as follows:
† Yellowish brown, marked with darker; fins without markings........*artedi*.
†† Upper side of head and back uniform black; lower part of sides of head and body with numerous spots; fins black, with brown rays...... ...*mulleri*.

8. **Steatogenes** Boulenger. (Fig. 11.)

Steatogenes Boulenger, Trans. Zool. Soc. London, XIV, 1898, 428.

Type: *Rhamphichthys elegans* Steindachner.

a. Head chubby, upper profile convex; head 1.5 in the depth. A. 165 to 176 (Steindachner)............. ....*elegans*, 20.

20. STEATOGENES ELEGANS (Steindachner).

Rhamphichthys (*Brachyrhamphichthys*) *elegans* Steindachner, Fisch-f. Cauca and Guayaquil, 37, 1880, **Barra do Rio Negro.**

Brachyrhamphichthys elegans, Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 62.

Steatogenys elegans, Boulenger, Trans. Zool. Soc., XIV, 428, 1898 (Rio Jurua).

Rhamphichthys (*Brachyrhamphichthys*) *mirabilis* Steindachner, *l. c.*, pl. IX, figs. 1 and 1*a*.

Habitat: Barra do Rio Negro.

9. **Eigenmannia** Jordan & Evermann. (Figs. 14 and 16.)

Sternopygus Müller & Troschel, Horæ Ichthyol., III, 13 (species).

Cryptops Eigenmann, Ann. N. Y. Ac. Sci., VII, 626 (*humboldtii*); preoccupied.

Eigenmannia Jordan & Evermann, Fishes North and Mid. Amer., I, 341, 1896 (substituted for *Cryptops*).

Type: *Sternopygus humboldtii* Steindachner.

Geographical distribution of the species: On the eastern slope from Magdalena to La Plata, Pacific Slope of Panama.

a. "Maxillary shorter than the diameter of eye; eye without free lid, a little longer than snout or interocular space; mouth very narrow; upper jaw overlapping lower; upper profile of head descending in a curve; vent a little behind vertical of posterior border of eye; pectoral fin as long as head minus snout; A. 175, originating below middle of pectoral; depth of body greater than length of head, 7.5 in length to end of anal; tail produced beyond anal in a very long appendage terminating filiform and measuring half total length without head; scales very small. Uniform pale brownish; anal fin white." (Boulenger.) *macrops*, 21.

aa. Maxillary about equal to orbit, the mouth small.

b. Ventral profile much more strongly convex than dorsal; head strongly compressed, triangular in profile; upper profile of head nearly straight, a slight depression over eyes; eye nearly 2 in snout; snout 3 to 3.25 in head; interorbital 3.25 to 3.7; width of head 2 to 2.25.............. .... *humboldtii*, 22.

bb. Dorsal and ventral profiles equally convex; head less compressed; upper profile of head straight; eye nearly 2 in snout; snout 3 in head; interorbital about 3; width of head 1.75 to 2 in its length.. *virescens*, 23.

aa. Maxillary about twice width of orbit.

c. Eye 2 in snout; jaws equal; anal beginning below posterior third of pectoral; a large blackish spot at origin of lateral line; A. 212.. *axillaris*,[1]. 24.

cc. Eye 2.5 in snout; lower jaw longer than upper; anal beginning below origin of pectoral; color uniform; A. 230. *troschelii*, 25.

21. EIGENMANNIA MACROPS (Boulenger).

Sternopygus macrops Boulenger, Ann. Mag. Nat. Hist. (6), XX, 305, **Polaro River, British Guiana.**

22. EIGENMANNIA HUMBOLDTII (Steindachner).

Sternopygus humboldtii Steindachner, Fisch-f. Magd. Str. 55, pl. XIV, 1878, **Magdalena**; id. Flussf. Südam., 1, 21, 1879 (Mamoni R. at Chepo); id. Fisch-fauna Cauca and Guayaquil, 36, 1880 (Cauca); Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 62; Steindachner, Denk. Akad. Wiss. Wien, LXXII, 147, 1902 (Baranquilla on Rio Magdalena).

Cryptops humboldtii, Eigenmann, Ann. N. Y. Ac. Sci., VII, 1894, 625 (Marajo.).

Eigenmannia humboldti, Jordan & Evermann, Fishes North and Mid. Amer., 341, 1896.

Habitat: Marajo, Magdalena and Mamoni.

23. EIGENMANNIA VIRESCENS (Valenciennes).

Sternarchus virescens Valenciennes, in d'Orb., Voy. Am. Merid., Poiss., 11, pl. 13, fig. 2, 1847.

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[1] Steindachner considers this identical with *troschelii*.

Sternopygus virescens, Kaup, Apod., 137; Steindachner, Die Gymnotidæ, 12, 1868 (Matto Grosso: Rio Negro, Guaporé, Marabitanos: Irisanga: Guaporé): Günther, Proc. Zool. Soc. 1868, 229 (Xeberos); Günther, Cat., VIII, 7, 1870 (Surinam; Lagoa Santa; Xeberos); Cope, Proc. Am. Philos. Soc. 1870, 570 (Pebas; Rio Parana): Cope, Proc. Ac. Nat. Sci. Phila. 1871, 257 (Ambyiacu); Lütken, Velhas-Flodens Fiske, 247 and XIX, 1875 (Lagoa Santa and Rio das Velhas); Peters, Mb. Ak. Wiss. Berlin, 1877, 473 (Apuré); Steindachner, Fisch-f. Magd. Stromes, 55, pl. XIV, fig. 4, 1878; Cope, Proc. Am. Philos. Soc. 1878, 682 (Peruvian Amazon); Cope, Proc. Am. Philos. Soc. 1894, 93 (Rio Grande do Sul); Boulenger, Trans. Zool. Soc., XIV, 38, 1894 (Descalvados).

Cryptops virescens, Eigenmann, Ann. N. Y. Ac. Sci., VII, 1894, 626; Eigenmann, *l. c.*, 635 (Rio Grande do Sul); Boulenger, Boll. Torino, X, 3, 1895 (Colonia Risso, Paraguay); Boulenger, Am. Mus. Civico, Genova, 1898, 127 (Puerto 14 de Mayo).

Eigenmannia virescens, Eigenmann & Norris, Revista Mus. Paulista, IV, 549 (Piracicaba); Eigenmann & Kennedy, Proc. Ac. Nat. Sci. Phila. 1903, 530 (Arroyo Trementina; Paraguay).

Sternopygus tumifrons Müller & Troschel, Hor. Ichthyol., III, 14, 1849, **South America.**

Sternopygus lineatus Müller & Troschel, *l. c.*, III, 14, 1849, **Lake Amucu in Guiana**; Kaup, Apod., 138; Steindachner, Die Gymnotidæ, 261, 1868.

Cryptops lineatus, Eigenmann, Ann. N. Y. Ac. Sci., VII, 1894, 635 (Rio Grande do Sul).

Sternopygus microstomus Reinhardt, Videnk. Meddel. Naturf. For. Kjöbenh. 1852 or Wiegm. Arch. 1854, 181.

Sternopygus limbatus Schreiner & Ribeiro, Arch. Mus. do Rio de Janeiro, XII, 6, 1902, **Amazonas.**

Habitat: Rio Magdalena to Rio de La Plata, East of the Andes.

The specimens of *lineatus* mentioned by Eigenmann from Rio Grande do Sul have a more strongly arched ventral profile resembling in this respect *humboldtii*, but they have a broad head, young examples from Paraguay have the same form and differ in this respect from the bulk of the Rio Grande specimens recorded by Eigenmann.

24. EIGENMANNIA AXILLARIS (Günther).

Sternopygus axillaris Günther, Cat., VIII, 8, 1864, **Para**; Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 62.
Habitat: Para.

25. EIGENMANNIA TROSCHELI (Kaup).

Sternopygus virescens, Müller & Troschel, Horæ Ichthyol., III, 14, 1849 (Guiana); not of Valenciennes.

Sternopygus troscheli Kaup, Apod., 139, 1856; Steindachner, Die Gymnotidæ, 12, 1868 (Barra do Rio Negro); Günther, Cat., VIII, 8, 1864; Cope, Proc. Am. Philos. Soc. 1878, 682 (Peruvian Amazon); Steindachner, Fisch-f. Magdal., 56, 1878 (note); Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 62.
Habitat: Amazonas from Manaos to Peru.

10. **Gymnotus** Linnæus. (Figs. 17–19.)

Gymnotus Linnæus, Syst. Nat., ed. X, 246, 1758 (type: *Gymnotus carapo* Linnæus); ed. XII, i, 427, 1766 (*carapo; electricus; albifrons; rostratus; asiaticus*).

Gymnotus Lacépède.

Gymnotus Cuvier Règne Animal, 1st ed., II, 235, 1817 (sp. *electricus*, *æquilabiatus*); Günther, Cat., VIII, 10, 1870 (restricted to *electricus*).

Sternopygus Müller & Troschel, Horæ Ichthyol., III, 13, 1849 (*macrurus = carapo; tumifrons = virescens; virescens; lineatus; æquilabiatus*).

Sternopygus Eigenmann, Ann. N. Y. Ac. Sci., VII, 1894, 326 (restricted to *carapo*) to include *carapo*, *æquilabiatus* and *obtusirostris*).

Gymnotes Gill, Proc. Ac. Nat. Sci. Phila. 1864, 152 (*æquilabiatus*).

The first species of the *Sternopygidæ* mentioned in literature is the *carapo* of Marcgrav.

The name *Gymnotus* was apparently introduced by Artedi in his Genera Piscium, p. 25, and Synonymia, p. 43, and the only species mentioned by him is the *carapo* of Marcgrav. Linnæus, in adopting the name *Gymnotus* in the 10th edition enumerated only *carapo*, but in the 12th edition included in it all the then known species of the family *Gymnotidæ* as well as the electric eel. In his 12th edition he recognized *carapo*, *electricus*, *albifrons*, *rostratus* and *asiaticus* in the order named.

The name *Gymnotus* was used by Bloch for *carapo* and *electricus*, by Cuvier for *electricus* and *æquilabiatus*, the latter species not known to Linnæus. It was more formally restricted to *electricus* by Swainson.

In 1864 Gill properly contended that the genus *Gymnotus* "had been originally founded solely on the *Gymnotus carapus*, and that even after the introduction of the *Gymnotus electricus* into the system, *G. carapus* was retained as the first of the genus. * * * The name *Gymnotus* must be retained for *G. carapus*. * * *"

Geographic distribution of the species: Atlantic slope, Magdalena south to Rio das Velhas and Paraguay; Pacific slope at Guayaquil.

a. Snout pointed, 3 or more in head; profile nearly straight.
  b. Depth greater than length of head; upper profile straight or convex; upper lip usually slightly projecting; a dusky spot over gill-opening..*carapo*, 26.
  bb. Depth less than length of head; upper profile slightly concave; jaws equal; a light longitudinal streak; body with numerous small violet spots; A. 275 to 292............*æquilabiatus*, 27.
aa. Snout very blunt, 3 in head; upper profile convex; depth greater than length of head; upper lip projecting in adult; A. more than 300.................................... ....*obtusirostris*, 28.

26. GYMNOTUS CARAPUS Linnæus.

Marcgrav in Seba, Thesaur., III, tab. 32, figs. 3-4; Artedi, Genera Pisc., 25; Synonymia Pisc., 43; Amoen. Acad., I, 318, t. 14, f. 6.

Gymnotus Gronow, Mus. Ichthyol., I, 28, No. 72, 1754; Gronow, Zoophyl., no. 168, 1863.

Gymnotus carapo Linnæus, ed. X, 246, 1858; ed. XII, 427, 1766; Bloch, V, 59, tab. 157, fig. 2; Gronow, Syst., ed. Gray, 22, 1854.

Sternopygus carapus, Günther, Cat., VIII, 7, 1870; Lütken, Velhas Flodens Fiske, 247, and XIX, 1875 (Rio das Velhas); Peters, Mb. Akad. Wiss. Berlin, 1877, 473 (Apuré); Steindachner, Fisch-f. Magdalenen Str., 4, 1878 (Pará); Boulenger, Proc. Zool. Soc. 1887, 282 (Canelos); Steindachner, Flussf. Südam., II, 44, 1881 (Amazon from Pará to Teffé; Xingu at Porto do Moz; Lake Manacapuru; Rio Branco; Borba; Caiçara; Essequibo; Surinam; Maroni River in Guiana); Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 62; Perugia, Ann. Mus. Civico Storia nat. Genova, ser. 2, vol. X, 56, 1891 (Central Chaco); Eigenmann, Ann. N. Y. Ac. Sci., VII, 1894, 626 (Marajo); Boulenger, Trans. Zool. Soc., XIV, 38, 1896 (Paraguay).

Gymnotus macrurus, Bloch & Schneider, 522, 1801.

Sternopygus macrurus, Müller & Troschel, Horæ Ichthyol., III, 14, 1849; Kaup, Apod., 137; Steindachner, Die Gymnotidæ, 11, 1868 (Surinam; Rio Branco; Borba; Caiçara); Cope, Proc. Ac. Nat. Sci. Phila. 1871, 257, 1872 (Ambyiacu); id., Proc. Am. Philos. Soc. 1878, 57 (Peruvian Amazon).

Carapus macrourus, Cuvier, Règne Animal, ed. I, II, 237, 1817.

Carapus arenatus Eydoux & Souleyet, Voy. Bonite, Zool., I, p. 210, pl. 8, fig. 2, 1836.

Carapus sanguinolentus Castelnau, Anim. Am. Sud, Poiss., 85, pl. 32, fig. 1, 1855, **Urubamba or upper Ucayale.**

Sternopygus marcgravii Reinh., Vidensk. Meddel. Naturh. Foren. Kjöbenh., 1852; and Wiegm. Arch., 1854, 180.

Habitat: Orinoco south to Paraguay and Rio das Velhas.

27. GYMNOTUS ÆQUILABIATUS Humboldt.

Gymnotus æquilabiatus Humboldt, Recueil d'observat., Zool. et Anat. Comp., i, 46, pl. 10; Kaup. Apod., 142; Günther, Cat. VIII, 7, 1870.

Sternopygus æquilabiatus, Müller & Troschel, Horæ Ichthyol., III, 15, 1849; Steindachner, Fisch-f. Magdalenen Str., 53, pl. XIV, fig. 1, 1878 (Magdalena River); id. Fisch-f. Cauca and Guayaquil, 36 and 50, 1880 (Cauca and Guayaquil); Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 62: Boulenger, Boll. Univ. Torino, XIII, 1898 (Rio Guayas); Steindachner, Denkschr., Acad. Wiss. Wien, LXII, 59, 1902 (Rio Magdalena at Baranquilla).

Habitat: Magdalena basin and Guayaquil.

28. GYMNOTUS OBTUSIROSTRIS (Steindachner).

Sternopygus obtusirostris Steindachner, Flussf. Südam., II, 43, pl. II, fig. 3, 1881, **Amazon at Teffé**; **Lago Alexo**; **Manacapuru**; **Rio Madeira**; **Rio Puty**; Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 62.

Habitat: Amazonas and Rio Puty.

11. **Giton** Kaup. (Fig. 15.)

Carapus Cuvier, Règne Animal, ed. I, 237, 1817 (sp.).

Carapus Müller & Troschel, Horæ Ichthyol., III, 13 (*fasciatus*); not Carapus Rafinesque.

Giton Kaup in Dumeril, Analyt. Ichthyol., 201, 1856. Type: *Gymnotus fasciatus* Pallas.

Geographical distribution is that of the single species.

29. GITON FASCIATUS (Pallas).

Carapo Marcgr., Hist. Pisc., 170; Willoughby, Hist. Pisc., 115, tab. G 7, fig. 4.

Gymnotus Seba, Thesaur., III, tab. 32, fig. 1.

Gymnotus fasciatus, Pallas, Spicil. Zool., VII, 35; Schomburgk, Fishes of Guiana, 184, pl. 19, 1843 (Guiana).

Carapus fasciatus, Cuvier, Règne Animal, ed. I, 237, 1817; Müller & Troschel, Horæ Ichthyol., III, 13, 1849; Castelnau, Anim. Amer. Sud, 85, 1855 (Amazon), Kaup, Apod., 139; Steindachner, Die Gymnotidæ, 13, 1868 (Caiçara; Cuyaba; Marabitanos; Surinam; Matto Grosso); Günther, Cat., VIII, 9, 1870 (Capim; Bahia; Surinam; British Guiana; Essequibo; Berbice; Trinidad; Is. Grenada; Rio Motagua); Hensel, Wiegm. Archiv, 89, 1870 (Guahyba;

Porto Alegre); Cope, Proc. Am. Philos. Soc. 1870, 570 (Pebas); Cope, Proc. Ac. Nat. Sci. Phila. 1871 (1872), 257, (Ambyiacu); Lütken, Velhas Flodens Fiske, 247 and XIX, 1875 (Rio das Velhas; Lagoa Santa and Rio San Francisco); Cope, Proc. Am. Philos. Soc. 1878, 682 (Peruvian Amazon); Boulenger, Proc. Zool. Soc. 1887, 282 (Canelos); Eigenmann & Eigenmann, Proc. U. S. Nat. Mus., XIV, 1891, 62; Perugia, Ann. Mus. Civico Storia Nat. Genova, 2nd. ser., vol. X, 56, 1891 (Central Chaco); Eigenmann, Ann. N. Y. Ac. Sci., VII, 1894, 626 (Braret); Eigenmann, *l. c.*, 635 (Rio Grande do Sul); Cope, Proc. Am. Philos. Soc. 1894, 93 (Rio Grande do Sul); Boulenger, Boll. Torino, X, 3, 1895 (Colonia Risso and Villa Rica, Paraguay); Boulenger, Ann. Mus. Civico, Genova 1898, 127 (Puerto, 14 de Mayo).

Giton fasciatus Kaup in Dumeril, Analyt. Ichthyol., 201, 1856; Jordan & Evermann, Fishes North and Mid. Amer., 340, 1896 (Guatemala to Rio de la Plata); Eigenmann & Kennedy, Proc. Ac. Nat. Sci. Phila. 1894, 530 (Estancia La Armonia; Campo Grande; Arroyo Trementina).

Gymnotus albus Pallas, Spicil. Zool., VII, 36, Surinam; Bloch & Schneider, 523, 1801.

Carapus albus, Kaup, Apod., 140, 1856.

Gymnotus brachyurus Bloch, Taf. 157, fig. 1, 1787.

Gymnotus putaol Lacépède, His. Nat. Poiss., 11, 176, 1800.

Gymnotus carapo, Bloch & Schneider, 521, 1801.

Carapus brachyurus, Cuvier, Règne Animal, I, 237, 1817.

Carapus inæquilabiatus, Valenciennes, in d'Orb. Voy. Am. Merid., Poiss., 11, pl. 14, 1847 (La Plata).

Habitat: Rio Motagua South to Rio de la Plata.

TABLE SHOWING KNOWN GEOGRAPHIC DISTRIBUTION BY RIVER BASINS OF THE SPECIES OF GYMNOTIDÆ.

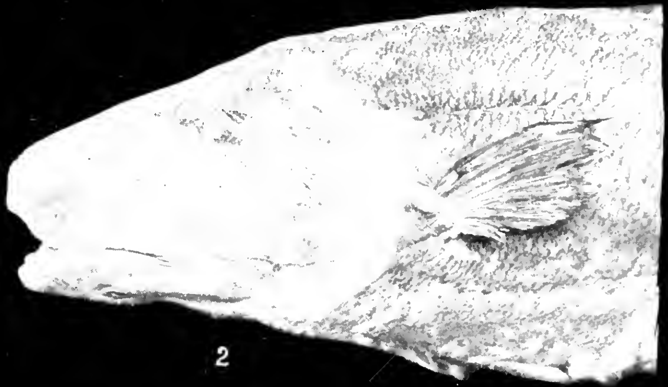
	Western Slope.	Central America.	Magdalena.	Orinoco.	Guianas.	Amazon.	Solimoes.	Marañon.	Rio Puty.	Rio San Francisco.	Rio Grande do Sul.	Paraguay.	Parana.	La Plata.	Bahia.
Sternarchus brasiliensis										*			*		
" albifrons				*	*	*	*	*				*			
" bonapartii						*	*	*							
" macrolepis						*	*								
Sternarchella schotti							*	*							
" balænops								*							
Sternarchogiton nattereri						*									
" sachsi				*											
Sternarchorhamphus macrostomus								*							
" mulleri						*									
" tamandua							*								
Sternarchorhynchus mormyrus (Marabitanos)								*							
Sternarchorhynchus oxyrhynchus					*										
" curvirostris								*							
Rhamphichthys rostratus					*		*								
" marmoratus				*	*	*	*	*				*		*	
" reinhardtii						*	*					*			
Hypopomus artedii					*										
" brevirostris			*			*	*					*			
Steatogenys elegans						*									
Eigenmannia macrops					*										
" humboldti	*	*	*												
" virescens				*	*	*	*	*		*	*	*	*		
" axillaris						*									
" troscheli					*		*	*							
Gymnotus carapus				*	*	*	*	*		*		*			
" æquilabiatus	*		*												
" obtusirostris						*	*		*						
Giton fasciatus		*		[1]	*	*		*		*	*	*		*	*

[1] Trinidad.

EXPLANATION OF PLATE VII.

FIG.	1.	*Sternarchus brasiliensis.*	Photograph by C. H. Eigenmann.
	2.	" *albifrons.*	" " "
	3.	" *macrolepis.*	After Steindachner.
	4.	*Sternarchella schotti.*	" "
	5.	*Sternarchogiton nattereri.*	" "

1



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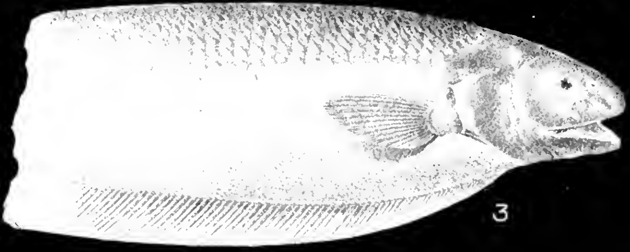

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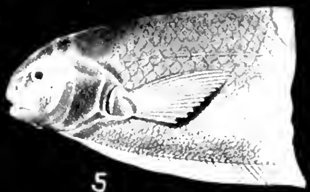

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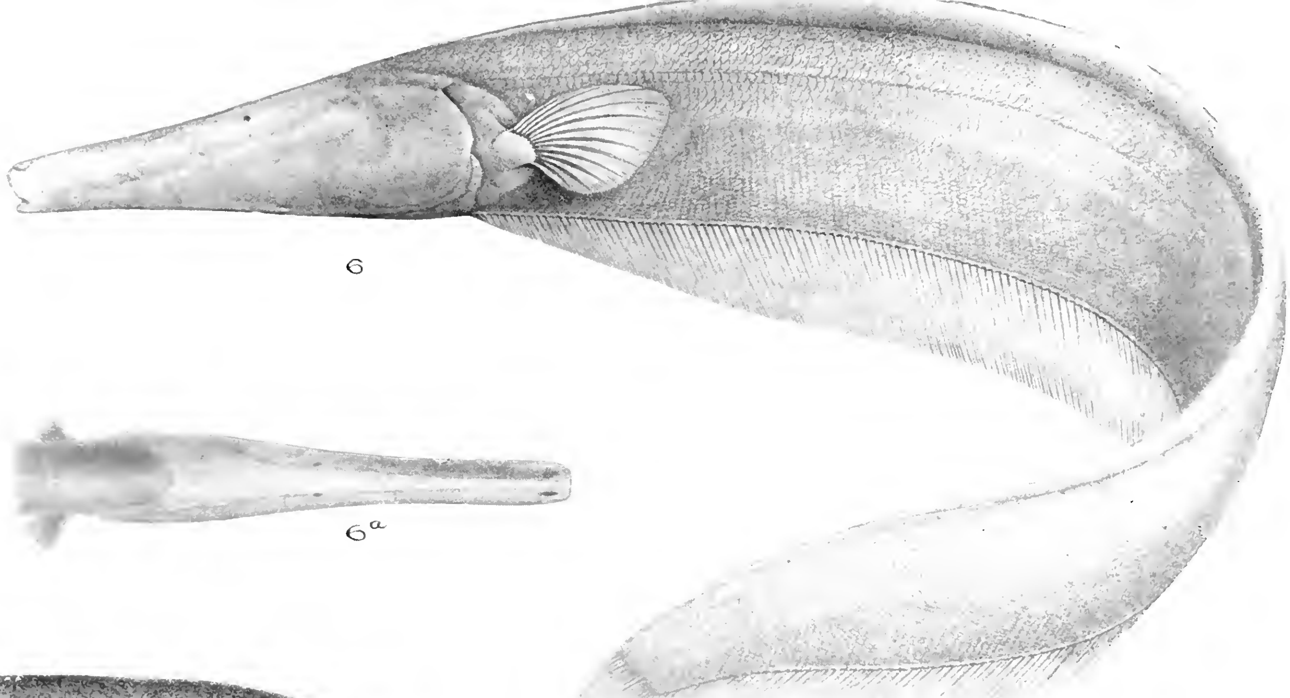
EXPLANATION OF PLATE VIII.

FIG. 6. *Sternarchorhamphus tamandua.* After Boulenger.
7. " *mulleri.* After Steindachner.
8. *Sternarchorhynchus mormyrus.* " "



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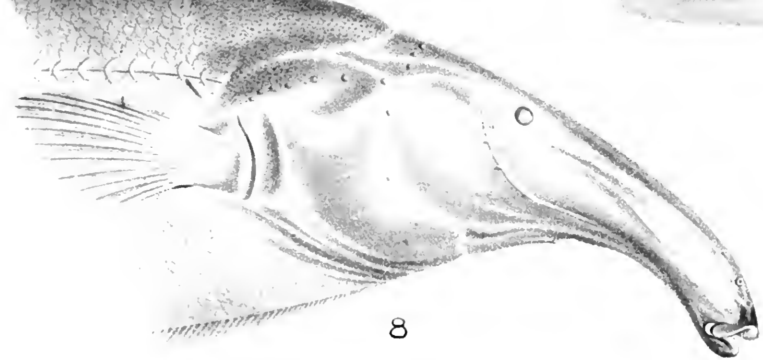

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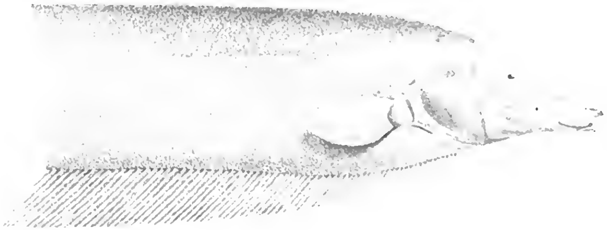

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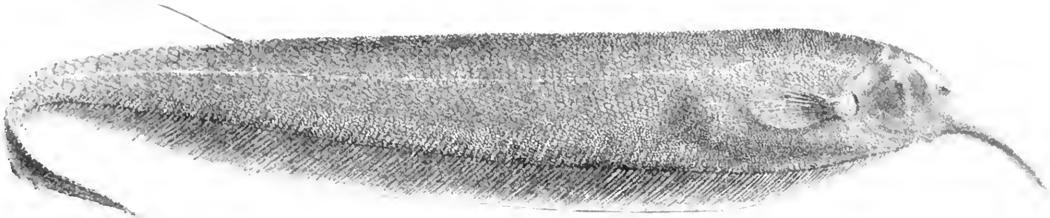
EXPLANATION OF PLATE IX.

FIG. 9. *Sternarchorhynchus curvirostris.* After Boulenger.
10. " *oxyrhynchus.* After Müller and Toschel.
11. *Steatogenys elegans.* After Steindachner.



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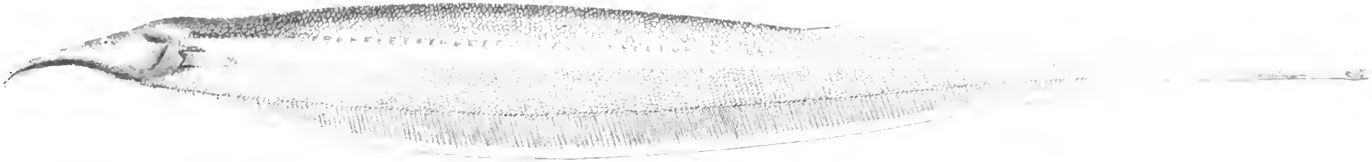

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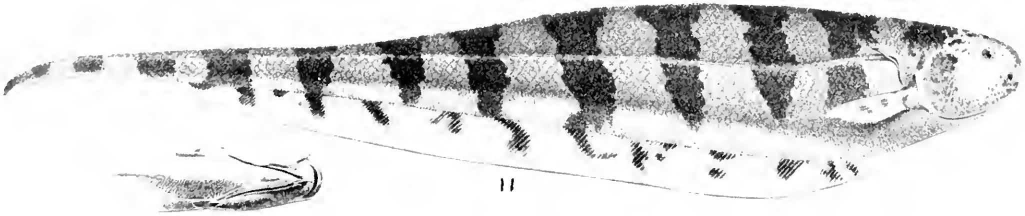

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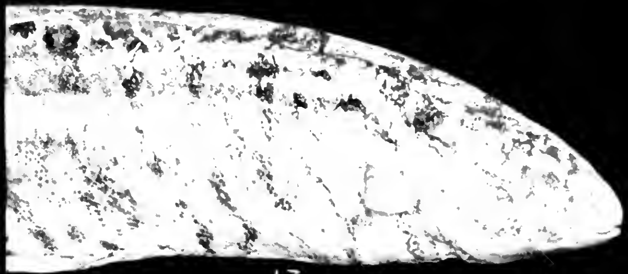
EXPLANATION OF PLATE X.

FIG. 12.	*Rhamphichthys marmoratus.*	Photograph	by C. H.	Eigenmann.
13.	*Hypopomus brevirostris.*	"	"	"
14.	*Eigenmannia virescens.*	"	"	"
15.	*Giton fasciatus.*	"	"	"

12



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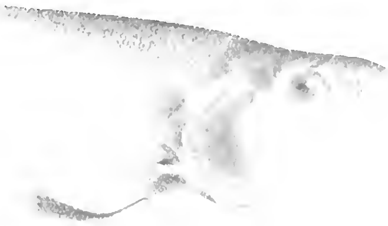
EXPLANATION OF PLATE XI.

Fig. 16. *Eigenmannia humboldtii*. After Steindachner.
17. *Gymnotus carapus*. " "
18. " *æquilabiatus*. " "
19. " *obtusirostris*. " "

19



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PROCEEDINGS

OF THE

WASHINGTON ACADEMY OF SCIENCES

VOL. VII, PP. 189–249. JULY 24, 1905

DECLINATIONS OF CERTAIN NORTH POLAR STARS DETERMINED WITH THE MERIDIAN CIRCLE.

BY HARRIET W. BIGELOW,

INSTRUCTOR IN ASTRONOMY IN SMITH COLLEGE.

THE stars whose right ascensions and declinations I have observed with the Meridian Circle are those requested by Dr. Auwers in the Astromische Nachrichten, No. 3440. They comprise a list of 21 stars between 84° 34′ and 88° 55′ north declination and in magnitude ranging from 5.3 to 7.5. As Dr. Auwers points out, the Berliner Jahrbuch at present gives but 10 stars of declination above 82°, 5 of these being above 85°; and these are not symmetrically placed in right ascension leaving several gaps of 2 or 3 hours when an observer would find no fundamental star of high declination available. The present observations were undertaken to furnish accurate places of additional stars of high declination for use when such are needed in determining instrumental constants.

The observations were begun in October, 1901, and extended through the period to the end of June, 1903. The right ascensions have not yet been reduced.

The Walker Meridian Circle was built by Pistor and Martins of Berlin in 1854. The telescope tube is heavy, unsymmetrical, and shows considerable flexure; the object-glass and eye-ends are not interchangeable, as in many modern instruments. The objective, of 6.3 inches aperture, was examined at the Physical Laboratory. The focal length, 251.6 cm. or 8 ft. 0.8 in., was determined by measurements on the negative unit planes. The radii of curvature, measured with the spherometer, were found to be 165. 7cm. for the outer curve, 274.4 cm. for the inner curve. The structure of the glass was examined by means of Nicol prisms at conjugate foci. For perpendicular position of the prisms the lens instead of being entirely dark shows irregular light portions extending toward the center, due to irregular polarization in the glass. Practically, however, the lens gives excellent star images for meridian circle work, *i. e.*, small, round disks, of uniform size across the entire field.

The graduated circles of the instrument are 37½ inches in diameter. The fine circle, which was the one employed, is graduated to 2′ and is read by 4 microscopes of 16 magnifying power reading to tenths of a second of arc. Each microscope has been furnished with two sets of threads one and a half revolutions apart to eliminate periodic error. For a reading two divisions of the circle were pointed on, the micrometer screw being turned always one half revolution. The readings were corrected for error in the run.

The micrometer eye-piece was obtained a few years ago from the Repsolds. It contains 25 verticle threads in groups of 5, and 2 horizontal threads about 5″ apart. There is no declination micrometer screw. Settings were made with the tangent screw of the instrument, bringing the star to the point half-way between the horizontal threads. It was usually found possible to make 3 or more pointings with the corresponding readings of the microscopes while the star was crossing the field. The positions off the meridian were symmetrically chosen to avoid error caused by possible inclination of the wires. The reductions to the meridian were made according to the formula

$$z = z' - \sin 2\delta' \frac{\sin^2 \frac{1}{2}t}{\sin 1''}$$

where δ' is the apparent declination. In this form a second term becomes negligible. (See Leyden Observations, Vol. VI, p. LX.) Tables were made out for each star from which the correction could be taken with the declination and hour angle as arguments.

Observations for nadir were made about every 3 hours. These were obtained by turning the telescope over a mercury basin and observing the reflection of the horizontal threads by means of a collimating eye-piece. Four settings were made, the mercury basin being turned 180° in the middle of the set. When successive nadirs differed by more than 0''.50, it was assumed that the difference was directly proportional to the time; when the difference was less than 0''.50 the straight mean was taken. Occasionally during observations for nadir the instrument seemed to move after a setting had been made, showing either that it was under a strain, or possibly that the surface of the mercury changed slightly.

The plan was to obtain for each star, both at upper and lower culminations, 2 observations in each of the four following positions: clamp west, direct; clamp west, reflected; clamp east, direct; clamp east, reflected. This plan was not entirely carried out as the tables show, in part due to the difficulty in obtaining reflected observations. These were often prevented by wind or unsteady seeing. Often, too, reflected observations were prevented by trains on the Michigan Central Railroad, and sometimes by the shutting of a door in another part of the building. Nevertheless, nearly as many reflected observations were obtained as direct. They seem to be quite as consistent among themselves as the direct; perhaps they are in a sense selected observations. Each night's observing list included at least one of the Berliner Jahrbuch stars.

Advantage in combining reflected and direct observations is found in the fact that different sets of divisions on the circle are employed, thus largely eliminating division errors, and in the fact that the sign of the sine flexure is reversed. In the mean of the 4 positions: W. D.; W. R.; E. D.; E. R.; the first 2 terms of the cosine flexure and the first term of the sine flexure are eliminated.

To determine the amount of the flexure the following formulæ were employed:

W. D. $\zeta = z_1 + a' \cos z + b' \sin z - (180^\circ + N) + a'$
W. R. $(180^\circ - \zeta) = z_2 - a' \cos z + b' \sin z - (180^\circ + N) + a'$
E. D. $(360^\circ - \zeta) = z_3 + a' \cos z - b' \sin z - (180^\circ + N) + a'$
E. R. $(180^\circ + \zeta) = z_4 - a' \cos z - b' \sin z - (180^\circ + N) + a'$

The coefficient of cosine flexure found was 1″.694; and of sine flexure, 0″.117. In the case of clamp west the circle readings increase from the zenith toward the north and the formula for flexure correction is

$$\zeta = z + 0''.162 - 1.''694 \cos z + 0''.117 \sin z - 1.''694$$

The large cosine flexure was also found by Dr. Hall. (See "Reprint from Report of Michigan Academy of Science," 1904.)

Corrections for division errors were not applied. Some examination of the circle was made to determine its general character. The mean of the 4 divisions, 0°, 90°, 180°, 270°, was assumed to be without error. In finding the errors of the intermediate divisions, taking also as a division the mean of 4 marks 90° apart, 2 microscope arms were set 100° apart, 110° apart, etc. Readings were then made on a number of 100° spaces, for instance, distributed symmetrically around the circle; these readings were taken forward and back so as to eliminate progressive changes in the instrument depending on the time. The mean of these readings was assumed to be the correct 100° space and was used for obtaining the error of the 100° mark on the circle. The microscopes were afterward changed 180° from their first position and the process repeated.

The 2 columns of division errors given show the changes produced by placing the microscopes in the two positions. Evidently the effect of gravity is considerable as might be expected from the structure of the circle, which is rather frail.

Divisions.		Division Errors.		Means.
100°	(vs. 10° etc.)	— 0″.11	— 0″.62	— 0″.36
110	20	— 0.33	— 0.84	— 0.58
120	30	— 0.50	— 0.58	— 0.54
130	40	— 0.72	— 0.62	— 0.67
140	50	— 0.70	— 0.62	— 0.66
150	60	— 0.34	— 0.94	— 0.64
160	70	+ 0.06	— 0.26	— 0.10
170	80	+ 0.40	+ 0.02	+ 0.21
180	90	0.00	0.00	0.00

Two tables of observed declinations are presented, the first giving the absolute declinations from the circle readings without correction for flexure or division errors; the second giving the declinations of the list stars from comparison with the one or more zero stars observed on the same night.

In Table I the observed zenith distances are given, corrected for runs, reduction to the meridian, and refraction. Bessel's refraction tables were employed, as prepared by Professor Eastman of the Naval Observatory. The standard barometer was repaired and tested a few years ago by the Weather Bureau Office in Washington. The thermometers also have been tested by them and by the weather bureau official at Lansing. During observations the thermometer was hung near the object glass of the telescope, and the readings were corrected when necessary, according to the table of corrections determined by the Weather Bureau Office.

The next column in Table I gives the observed zenith distances, reduced to Jan. 0.0 of the year of observation. These reductions were made with the "Independent Star Numbers" G, H, etc., given for each day in the Berliner Jahrbuch. They were checked by a sufficient number of identical reductions made with the Besselian Star Numbers, A, B, C, D, E, from the Berliner Jahrbuch and the star constants from Dr. Auwers's list in the Astronomische Nachrichten.

The zenith distances are then reduced to Jan. 0.0, 1900 and the means taken of the different observations of each position. In obtaining these means, a system of weights depending on the number of settings in each case was adopted as follows: probable error of one setting 0″.33; probable error of nadir determination 0″.25; probable error in refraction tables 0″.30, giving as weights:

No. of Settings.	Weight.
1	.72
2	.90
3	1.00
4	1.04
5	1.08
6	1.10
7	1.11

The reflected observations are also corrected for the position of the mercury basin, the correction being *h tan z* where *h* is height of telescope axes above the artificial horizon. This correction is 0″.04 for upper culmination, and 0″.03 for lower.

The mean of the 4 positions above pole combined with the mean of the 4 below gives the value for latitude corresponding to each star.

LATITUDE.

List Stars.	
Cephei Br. 256	49″.35
Cephei 157 Hs.	48.95
Cephei 158 Hs.	48.86
Cephei 109 Hs.	48.72
Urs. min. 4 B	48.71
Cephei 121 Hs.	48.48
Urs. min. 3 Hs.	48.42
32 H. Camel. pr.	48.70
“ “ “ seq.	49.08
Cephei 135 Hs.	48.75
Urs. min. 57 B	48.74
Cephei 3 Hs.	48.60
Cephei Gr. 3548	48.60
32 H. Cephei	48.72
36 H. Cephei	48.58
39 H. Cephei	48.61
Cephei 125 Hs.	48.72
Mean	48.74

B. J. Stars.	
43 H. Cephei	48″.74
Polaris	48.82
Gr. 750	48.68
51 H. Cephei	48.80
1 H Draconis	48.76
30 H. Camelop.	49.10
δ Urs. min.	48.94
λ Urs. min.	48.65
76 Draconis	48.80
Mean	48.81

The nine zero stars give 48″.81; the seventeen others, 48″.74. The value from the nine was given half weight and the adopted value for the latitude of Ann Arbor is 42°16′48″.76.

The value found recently by Dr. Hall is 48″.8 (see *Astronomical Journal*, 518).

This value of the latitude combined with the zenith distances gives for each star the eight values of declination in the last column of Table I. The mean of the four values above pole, with the mean of the four below, gives the final value of absolute declination.

In the case of the five stars not observed in all eight positions, adopted values of declination were found by correcting for flexure the places obtained and combining them with arbitrary weights as follows:

Cephei 147 Hs. $\frac{1}{4}$ (W. D. + 2 W. R. + E. D.) for declination above pole, combined with equal weight with position below pole.

Cephei 149 Hs. $\frac{1}{4}$ (2 W. D. + W. R. + E. R.) for declination above pole, and then treated like preceding star.

Camelop. s 664. Mean of the four positions above pole.

Urs. min. 33 Hs. $\frac{1}{2}$ (W. D. + E. D.) for position below pole, combined with half weight with observations above pole.

ε *Urs. min.* W. D. below pole combined with $\frac{1}{3}$ weight with the mean of the remaining observations.

In Table II in comparing the stars of the list with the zero stars observed on the same night, differential flexure was applied. No attempt has been made to give weights to the means depending on the number of zero stars employed. The final declinations obtained by the two methods are found to agree closely.

Table III gives a summary of the observed declinations together with the declinations given in Newcomb's "Fundamental Catalogue of Stars," and those given in the Berliner Jahrbuch for 1900, so far as the observed stars are found in either catalogue. The Berliner Jahrbuch for 1906 gives also in the appendix definitive corrections to the places as given in the main catalogue. The last column of Table III has been formed by adding these corrections to the catalogue places, and reducing from 1906 to 1900, employing the Berliner Jahrbuch values for precession without including proper motion. In the first column of observed declinations the five values obtained, as described above, from incomplete sets of observations are bracketed.

UNIVERSITY OF MICHIGAN,
ANN ARBOR, May, 1904.

TABLE I.—ABSOLUTE DECLINATIONS FOR 1900.0. 43 H. CEPHEI.

		Date of Obs.	No. of Settings.	Zenith Distance.				Declination. 1900.0
				Year of Obs. Obs.	Year of Obs. Jan. 0.0.	1900.0		
				43°26′		43°26′	Weighted Mean.	85°43′
Above Pole.	W.D.	Dec. 11, '01	3	88″.01	48″.38	28″.92	28″.92	17″.68
	W.R.	Dec. 5, '01	1	84.27	45.87	26.41	26.46	15.22
		Dec. 6, '01	1	84.49	45.90	26.44		
	E.D.	Nov. 18, '01	3	75.60	41.67	22.21	22.21	10.97
	E.R.	Oct. 22, '01	3	70.35	45.58	26.12	25.61	14.37
		Nov. 9, '01	3	75.46	44.49	25.03		
		Nov. 26, '01	1	81.16	45.03	25.57		
							25.80	14.56
				51°58′		51°59′		
Below Pole.	W.D.	Mar. 31, '03	2	54″.97	59″.70	58″.08	58″.42	12″.82
		May 29, '03	2	70.27	60.38	58.76		
	W.R.	Mar. 31, '03	2	53.80	58.53	56.91	57.08	14.16
		May 29, '03	1	68.73	58.84	57.22		
	E.D.	May 9, '02	1	80.19	76.18	55.10	54.65	16.59
		May 16, '02	1	80.59	75.23	54.15		
		Apr. 29, '03	3	60.20	56.30	54.68		
	E.R.	Feb. 21, '03	3	41.79	57.70	56.08	56.67	14.57
		May 8, '03	2	64.94	58.88	57.26		
							56.71	14.53
								14.55

TABLE I.—ABSOLUTE DECLINATIONS FOR 1900.0. POLARIS.

		Date of Obs.	No. of Settings.	Zenith Distance. Year of Obs. Obs.	Zenith Distance. Year of Obs. Jan. 0.0.	Zenith Distance. 1900.0.	Zenith Distance. 1900.0. Weighted Mean.	Declination. 1900.0.
				46°29′		46°29′		88°46′
Above Pole.	W.D.	Jan. 8, '02	4	100″.82	78″.42	40″.92	40″.58	29″.34
		Oct. 7, '02	4	90.04	77.75	40.25		
		Oct. 8, '02	5	92.38	79.69	42.19		
		Oct. 9, '02	3	91.31	78.21	40.71		
		Oct. 28, '02	4	97.05	76.81	39.31		
		Oct. 29, '02	4	97.81	77.24	39.74		
		Oct. 30, '02	5	98.89	77.99	40.49		
		Oct. 31, '02	7	99.71	78.47	40.97		
	W.R.	Dec. 6, '01	3	91.28	55.78	37.02	37.35	26.11
		Oct. 20, '02	5	91.15	74.02	36.52		
		Oct. 21, '02	3	92.19	74.64	37.14		
		Oct. 24, '02	6	94.52	75.73	38.23		
		Dec. 18, '02	3	110.89	75.06	37.56		
	E.D.	Nov. 12, '02	4	98.91	73.38	35.88	35.59	24.35
		Nov. 21, '02	2	102.73	74.06	36.56		
		Nov. 24, '02	5	102.34	72.76	35.26		
		Nov. 28, '02	3	103.86	73.18	35.68		
		Feb. 5, '03	2	110.06	90.80	34.57		
	E.R.	Dec. 2, '01	1	91.26	56.69	37.93	37.72	26.48
		Nov. 19, '02	2	103.08	75.11	37.61		
		Nov. 21, '02	3	103.72	75.05	37.55		
							37.81	26.57
				48°55′		48°56′		
Below Pole.	W.D.	Apr. 11, '02	1	65″.31	70″.46	47″.96	46″.96	24″.28
		Apr. 24, '02	5	68.91	70.05	47.55		
		Apr. 28, '02	2	70.55	70.60	48.10		
		June 8, '02	1	79.21	70.52	48.02		
		Mar. 21, '03	4	40.31	49.77	46.00		
		Mar. 25, '03	2	41.90	50.19	46.42		
		Mar. 28, '03	3	43.02	50.28	46.51		
		Mar. 29, '03	3	42.81	49.72	45.95		
		May 29, '03	2	60.23	50.56	46.79		
	W.R.	Apr. 29, '02	3	66.62	66.41	43.91	44.03	27.21
		June 3, '02	3	74.55	66.40	43.90		
		June 8, '02	3	74.31	65.62	43.12		
		Mar. 25, '03	3	39.91	48.20	44.43		
		May 29, '03	2	58.17	48.50	44.73		

TABLE I.—ABSOLUTE DECLINATIONS FOR 1900.0. POLARIS.—*Continued.*

		Date of Obs.	No. of Settings.	Zenith Distance.				Declination. 1900.0.
				Year of Obs.		1900.0.		
				Obs.	Jan. 0.0.			
				48°55′		48°56′	Weighted Mean.	
Below Pole.	E.D.	May 9, '02	2	67″.37	64″.34	41″.84	42″.06	29″.18
		May 13, '02	5	68.56	64.70	42.20		
		May 16, '02	2	69.26	64.69	42.19		
		May 24, '02	5	70.61	64.23	41.73		
		Mar. 1, '03	3	31.44	46.35	42.58		
		Apr. 28, '03	2	48.06	45.62	41.85		
		Apr. 29, '03	3	48.41	45.70	41.93		
		May 8, '03	2	50.97	45.89	42.12		
	E.R.	May 9, '02	1	69.74	66.71	44.21	45.09	26.15
		May 25, '02	3	73.58	67.04	44.54		
		Feb. 24, '03	3	32.59	48.77	45.00		
		Feb. 25, '03	3	33.04	48.99	45.22		
		Mar. 2, '03	4	34.29	48.93	45.16		
		Apr. 28, '03	4	52.05	49.61	45.84		
		May 8, '03	1	54.08	49.00	45.23		
							44.54	26.70
								26.64

TABLE I.—ABSOLUTE DECLINATIONS FOR 1900.0. CEPHEI BR. 256.

		Date of Obs.	No. of Settings.	Zenith Distance.				Declination. 1900.0.
				Year of Obs. Obs.	Year of Obs. Jan. 0.0.	1900.0.		
				40°48′		40°48′	Weighted Mean.	83°05′
Above Pole.	W.D.	Oct. 8, '02	5	87″.23	79″.21	44″.73	43″.66	32″.42
		Oct. 28, '02	2	92.94	77.75	43.27		
		Oct. 29, '02	3	92.87	77.33	42.85		
	W.R.	Jan. 22, '02	1	96.44	75.59	41.11	41.06	29.82
		Oct. 21, '02	1	87.41	74.74	40.26		
		Oct. 24, '02	3	89.75	76.02	41.54		
		Jan. 23, '03	2	109.85	91.54	39.82		
		Jan. 26, '03	2	112.23	93.90	42.18		
	E.D.	Nov. 24, '02	3	97.05	72.56	38.08	38.11	26.87
		Nov. 28, '02	1	98.36	72.63	38.15		
	E.R.	Dec. 2, '01	1	88.25	58.65	41.41	41.54	30.30
		Nov. 19, '02	1	98.71	75.84	41.36		
		Nov. 21, '02	2	99.69	76.17	41.69		
							41.09	29.85
				54°36′		54°37′		
Below Pole.	W.D.	June 8, '02	2	76″.65	67″.74	42″.22	41″.58	29″.66
		Mar. 21, '03	2	39.56	49.23	40.95		
	W.R.	Apr. 29, '02	3	65.17	65.57	40.05	40.22	31.02
		June 3, '02	2	73.98	65.88	40.36		
	E.D.	May 9, '02	1	65.79	63.37	37.85	38.19	33.05
		May 13, '02	3	67.39	63.91	38.39		
		May 16, '02	3	68.01	63.77	38.25		
	E.R.	May 25, '02	2	72.86	66.54	41.02	40.83	30.41
		Feb. 24, '03	2	33.34	48.85	40.57		
							40.21	31.03
								30.44

TABLE I.—ABSOLUTE DECLINATIONS FOR 1900.0. CEPHEI 147 HS.

		Date of Obs.	No. of Settings.	Zenith Distance. Year of Obs. Obs.	Zenith Distance. Year of Obs. Jan. 0.0.	Zenith Distance. 1900.0	Zenith Distance. 1900.0 Weight'd Mean.	Declination. 1900.0
Above Pole.				42°16′		42°16′		84°33′
	W.D.	Dec. 11, '01	2	75.″83	54.″17	40.″66	40.″83	29.″59 (wt. 1)
		Jan. 8, '02	3	83.15	67.99	40.99		
	W.R.	Dec. 5, '01	1	71.57	51.79	38.28	38.32	27.08 +.28[1] 27.36 (wt. 2)
	E.D.	Nov. 12, '02	1	72.60	63.36	36.36		
		Nov. 28, '02	2	76.95	62.19	35.19	35.34	24.10 (wt. 1)
		Feb. 5, '03	3	90.98	75.23	34.75		
	E.R.							
								[27.10]
Below Pole.				53°08′		53°09′		
	W.D.	June 14, '02	3	90.″17	80.″39	47.″39	46.″90	24.″34
		Mar. 29, '03	1	56.53	65.73	46.21		
	W.R.	June 3, '02	1	84.67	77.37	44.37		
		Mar. 25, '03	2	54.18	64.35	44.83	44.61	26.63
		Mar. 28, '03	2	54.55	64.00	44.48		
	E.D.	May 9, '02	1	75.79	75.40	42.40		
		May 16, '02	1	77.34	74.88	41.88	41.69	29.55
		Apr. 9, '03	3	54.32	60.56	41.04		
	E.R.	May 21, '02	2	81.83	77.94	44.94		
		May 22, '02	1	82.11	77.95	44.95		
		June 26, '02	1	89.46	77.54	44.54	45.21	26.03
		Apr. 28, '03	1	65.55	66.16	46.64		
							44.60	26.64
								[26.87]

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[1] Cos flexure and absolute term.

TABLE I.—ABSOLUTE DECLINATIONS FOR 1900.0. CEPHEI 149 HS.

		Date of Obs.	No. of Settings.	Zenith Distance.				Declination. 1900.0.
				Year of Obs. Obs.	Jan. 0.0.	1900.0.		
				44°03′		44°03′	Weighted Mean.	86°19′
Above Pole.	W.D.	Dec. 11, '01	1	39″.80	22″.63	10″.77	10″.75	59″.51 −2.75[2] 56.76 (wt. 2)
		Jan. 8, '02	2	47.48	34.43	10.74		
	W.R.	Jan. 22, '02	3	47.34	31.68	7.99	7.20	55.96
		Feb. 15, '02	2	47.41	29.92	6.23		
	E.D.	Nov. 24, '02	3	40.15	31.40	[7.71][1]		
	E.R.	Nov. 19, '02	3	38.76	31.73	8.04	8.15	56.91
		Nov. 21, '02	2	39.60	31.88	8.19		
								[56.60]
				51°22′		51°23′		
Below Pole.	W.D.	June 8, '02	2	61″.26	53″.17	16″.86		
		June 13, '02	1	62.99	53.67	17.36	17″.32	53.92
		June 14, '02	3	63.58	54.02	17.71		
	W.R.	Apr. 29, '02	3	46.11	49.69	13.38	13.59	57.65
		June 3, '02	3	56.86	50.06	13.75		
	E.D.	May 8, '02	1	44.87	45.68	9.37		
		May 13, '02	3	48.02	47.30	10.99	10.48	60.76
		May 25, '02	2	51.40	47.12	10.81		
	E.R.	May 21, '02	5	53.93	50.81	14.50	15.01	56.23
		May 22, '02	3	55.22	51.80	15.49		
							14.10	57.14
								[56.87]

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[1] There is evidently a large error in this value; probably due to an error in the original ecord.

[2] Cos flexure and absolute term.

TABLE I.—ABSOLUTE DECLINATIONS FOR 1900.0. GR. 750.

		Date of Obs.	No. of Settings.	Zenith Distance. Year of Obs. Obs.	Zenith Distance. Year of Obs. Jan. 0.0.	Zenith Distance. 1900.0.	Zenith Distance. 1900.0. Weighted Mean.	Declination. 1900.0.
				43° 00′		43° 00′		85° 17′
Above Pole.	W.D.	Oct. 28, '02	3	57″.07	62″.55	43″.29	43″.02	31″.78
		Oct. 30, '02	3	57.05	62.01	42.75		
	W.R.	Jan. 22, '02	3	71.12	58.06	38.80	39.51	28.27
		Feb. 15, '02	1	74.13	58.35	39.09		
		Dec. 18, '02	2	69.97	58.82	39.56		
		Jan. 26, '03	3	80.52	69.20	40.34		
	E.D.	Nov. 24, '02	3	60.51	57.29	38.03	37.36	26.12
		Feb. 5, '03	3	78.72	66.07	37.21		
		Feb. 13, '03	2	79.15	65.65	36.79		
	E.R.	Nov. 21, '02	2	61.67	59.49	40.23	40.27	29.03
							40.04	28.80
				52° 25′		52° 25′		
Below Pole.	W.D.	June 8, '02	1	31″.91	24″.35	43″.61	44″.64	26″.60
		June 13, '02	1	34.14	25.36	44.62		
		June 14, '02	3	35.47	26.41	45.67		
		Mar. 29, '03	4	5.50	15.51	44.37		
	W.R.	Apr. 29, '02	1	18.79	23.10	42.36	42.81	28.43
		June 3, '02	3	29.71	23.51	42.77		
		June 5, '02	3	29.83	23.02	42.28		
		Mar. 28, '02	3	4.48	14.72	43.58		
	E.D.	May 8, '02	1	17.08	18.61	37.87	39.49	31.75
		May 25, '02	1	24.36	20.77	40.03		
		Apr. 9, '03	2	3.28	10.97	39.83		
		Apr. 27, '03	2	8.45	11.15	40.01		
	E.R.	May 21, '02	1	25.92	23.52	42.78	43.42	27.82
		May 22, '02	1	27.15	24.43	43.69		
		June 24, '02	1	36.62	25.12	44.38		
		June 26, '02	2	35.48	23.57	42.83		
							42.59	28.65
								28.72

TABLE I.—ABSOLUTE DECLINATIONS FOR 1900.0. CEPHEI 157 HS.

		Date of Obs.	No. of Settings.	Zenith Distance.				Declination. 1900.0
				Year of Obs. Obs.	Year of Obs. Jan. 0.0	1900.0	1900.0 Weighted Mean.	
				43°33′		43°32′		85°49′
Above Pole.	W.D.	Feb. 22, '02	3	25″.12	11″.70	60″.91	60″.72	49″.48
		Feb. 24, '02	3	24.88	11.31	60.52		
	W.R.	Feb. 13, '02	4	20.25	7.70	56.91	56.98	45.74
		Feb. 15, '02	2	20.55	7.76	56.97		
	E.D.	Mar. 5, '02	3	19.64	5.82	55.03	54.64	43.40
		Mar. 6, '02	1	18.93	5.10	54.31		
		Feb. 5, '03	2	19.87	10.60	54.46		
	E.R.	Feb. 24, '03	1	24.76	13.24	57.10	57.22	45.98
		Feb. 26, '03	2	25.01	13.39	57.25		
							57.39	46.15
				51°52′		51°53′		
Below Pole.	W.D.	June 9, '02	3	83″.48	76″.87	27″.66	27″.36	43″.88
		June 13, '02	5	84.62	76.83	27.62		
		Mar. 29, '03	4	60.47	70.65	26.79		
	W.R.	June 3, '02	3	78.36	73.54	24.33	24.63	46.61
		June 5, '02	1	78.70	73.27	24.06		
		Mar. 28, '03	3	58.80	69.12	25.26		
	E.D.	June 16, '02	3	80.77	72.11	22.90	22.16	49.08
		June 17, '02	3	79.56	70.62	21.41		
	E.R.	June 24, '02	4	85.12	74.23	25.02	24.68	46.56
		June 26, '02	3	84.90	73.48	24.27		
							24.71	46.53
								46.34

TABLE I.—ABSOLUTE DECLINATIONS FOR 1900.0. CEPHEI 158 IIS.

		Date of Obs.	No. of Settings.	Zenith Distance.				Declination. 1900.0.
				Year of Obs.		1900.0.		
				Obs.	Jan. 0.0.			
				42°52′		42°51′		85°08′
							Weighted Mean.	
Above Pole.	W.D.	Jan. 16, '02	3	12″.84	9″.29	64″.07	63″.97	52″.73
		Feb. 15, '02	3	18.92	8.65	63.43		
		Feb. 22, '02	1	21.01	9.80	64.58		
	W.R.	Jan. 22, '02	2	10.45	5.27	60.05	59.99	48.75
		Feb. 13, '02	3	15.04	5.08	59.86		
	E.D.	Mar. 4, '02	3	15.50	3.45	58.23	58.64	47.40
		Mar. 5, '02	3	16.38	4.27	59.05		
	E.R.	Mar. 6, '02	2	19.20	7.05	61.83	61.63	50.39
		Feb. 24, '03	1	18.69	9.07	61.29		
		Feb. 25, '03	1	19.09	9.36	61.58		
		Mar. 2, '03	2	19.55	9.38	61.60		
							61.06	49.82
				52°34′		52°34′		
Below Pole.	W.D.	June 5, '02	3	24″.29	19″.82	25″.04	23″.88	47″.36
		June 9, '02	3	24.33	18.65	23.87		
		Mar. 29, '03	3	5.10	14.94	22.72		
	W.R.	June 3, '02	2	17.87	14.01	19.23	20.48	50.76
		Mar. 28, '03	2	3.96	13.89	21.67		
	E.D.	June 16, '02	3	21.06	13.27	18.49	18.28	52.96
		June 17, '02	3	20.93	12.85	18.07		
	E.R.	May 21, '02	2	17.14	17.19	22.41	22.27	48.97
		May 22, '02	3	17.11	16.87	22.09		
							21.23	50.01
								49.92

TABLE I. ABSOLUTE DECLINATIONS FOR 1900.0. 51 H. CEPHEI.

		Date of Obs.	No. of Settings.	Zenith Distance.				Declination. 1900.0.
				Year of Obs.		1900.0.		
				Obs.	Jan. 0.0.			
				44°55′		44°55′	Weighted Mean.	87°12′
Above Pole.	W.D.	Mar. 29, '02	1	34″.87	25″.43	34″.93	34″.88	23″.64
		Mar. 25, '03	3	28.98	20.52	34.84		
	W.R.	Feb. 15, '02	2	25.09	21.52	31.02	31.06	19.82
	E.D.	Mar. 5, '02	1	26.24	19.02	28.52	28.48	17.24
		Mar. 24, '02	1	28.11	18.74	28.24		
		Feb. 6, '03	3	14.38	14.30	28.62		
	E.R.	Mar. 6, '02	3	30.89	23.48	32.98	32.66	21.42
		Mar. 19, '02	3	32.47	23.56	33.06		
		Feb. 13, '03	3	19.64	17.60	31.92		
		Feb. 25, '03	2	23.28	18.49	32.81		
		Feb. 26, '03	3	22.77	17.74	32.06		
		Mar. 2, '03	4	24.40	18.57	32.89		
							31.77	20.53
				50°30′		50°30′		
Below Pole.	W.D.	June 13, '02	3	68″.16	64″.27	54″.77	52″.92	18″.32
		June 9, '03	2	69.49	66.12	51.80		
		June 14, '03	1	70.92	66.09	51.77		
	W.R.	June 27, '02	1	68.30	60.04	50.54	50.84	20.40
		June 9, '03	1	69.12	65.75	51.43		
		June 14, '03	2	69.68	64.85	50.53		
	E.D.	June 17, '02	1	62.41	57.23	47.73	47.92	23.32
		Apr. 27, '03	4	55.60	62.37	48.05		
	E.R.	June 26, '02	2	67.79	59.83	50.33	50.82	20.42
		June 25, '03	2	73.90	65.57	51.25		
							50.62	20.62
								20.57

TABLE I.—ABSOLUTE DECLINATIONS FOR 1900.0. CEPHEI 109 HS.

		Date of Obs.	No. of Settings.	Zenith Distance.				Declination. 1900.0
				Year of Obs.		1900.0		
				Obs.	Jan. 0.0.			
				42°03′		42°03′	Weighted Mean.	84°20′
Above Pole.	W.D.	Mar. 29, '02	3	51″.95	45″.37	64″.40	64″.26	53″.02
		Apr. 11, '02	2	52.46	45.07	64.10		
	W.R.	Feb. 15, '02	2	37.92	39.89	58.92	59.57	48.33
		Mar. 21, '03	2	36.83	31.56	60.14		
	E.D.	Mar. 4, '02	3	42.26	39.86	58.89	58.12	46.88
		Mar. 5, '02	3	40.94	38.31	57.34		
	E.R.	Mar. 19, '02	3	48.09	42.80	61.83	62.19	50.95
		Mar. 27, '02	3	49.80	43.44	62.47		
							61.04	49.80
				53°22′		53°22′		
Below Pole.	W.D.	June 5, '02	3	41″.96	42″.39	23″.36	23″.79	47″.45
		Oct. 6, '02	2	76.21	43.30	24.27		
	W.R.	Oct. 7, '02	1	73.04	40.01	20.98	21.21	50.03
		Oct. 18, '02	1	75.10	40.99	21.96		
		Oct. 20, '02	1	74.47	40.22	21.19		
		June 9, '03	2	49.84	49.28	20.70		
	E.D.	June 17, '02	2	40.80	37.99	18.96	18.76	52.48
		Sept. 15, '02	2	66.86	37.59	18.56		
	E.R.	June 26, '02	2	46.79	41.34	22.31	22.34	48.90
							21.52	49.72
								49.76

TABLE I.—ABSOLUTE DECLINATIONS FOR 1900.0. URS. MIN. 4 B.

		Date of Obs.	No. of Settings.	Zenith Distance.				Declination. 1900.0
				Year of Obs.		1900.0.		
				Obs.	Jan. 0.0.			
				46°38′		46°39′		88°55′
							Weighted Mean.	
Above Pole.	W.D.	Mar. 29, '02	2	61″.30	54″.32	14″.20	13″.52	62″.28
		Mar. 25, '03	2	49.13	42.89	12.83		
	W.R.	Mar. 21, '03	3	45.83	40.17	10.11	10.14	58.90
		Mar. 25, '03	4	46.39	40.15	10.09		
	E.D.	Mar. 21, '02	1	54.09	48.15	8.03	7.60	56.36
		Mar. 24, '02	1	53.31	46.94	6.82		
		Mar. 25, '02	1	54.41	47.91	7.79		
		Feb. 5, '02	4	32.12	37.66	7.60		
		Feb. 6, '03	3	32.57	37.79	7.73		
	E.R.	Feb. 5, '03	4	35.56	41.10	11.04	11.06	59.82
		Feb. 24, '03	4	41.20	41.05	10.99		
							10.58	59.34
				48°47′		48°47′		
Below Pole.	W.D.	June 27, '02	1	39″.65	34″.18	14″.30	14″.88	56″.36
		Sept. 22, '02	3	66.61	35.15	15.27		
		Sept. 26, '02	1	67.01	34.79	14.91		
	W.R.	June 27, '02	4	36.29	30.82	10.94	10.93	60.31
		June 8, '03	3	40.53	40.80	10.86		
	E.D.	June 17, '02	3	31.92	29.51	9.63	9.63	61.61
	E.R.	June 26, '02	3	36.96	31.80	11.92	12.54	58.70
		June 25, '03	2	47.73	43.11	13.17		
							12.00	59.24
								59.29

TABLE I. ABSOLUTE DECLINATIONS FOR 1900.0. CEPHEI 121 HS.

		Date of Obs.	No. of Settings.	Zenith Distance.				Declination. 1900.0.
				Year of Obs. Obs.	Year of Obs. Jan. 0.0.	1900.0.		
				42°17′		42°18′	Weighted Mean.	84°34′
Above Pole.	W.D.	Feb. 22, '02	3	40″.32	45″.48	13″.12	12″.62	61.38
		Mar. 29, '02	3	48.02	44.49	12.13		
	W.R.	Apr. 15, '02	2	47.70	41.92	9.56	9.79	58.55
		Mar. 25, '03	1	31.78	28.63	10.11		
		Mar. 28, '03	2	31.91	28.18	9.66		
	E.D.	Mar. 4, '02	1	35.91	38.17	5.81	6.34	55.10
		Mar. 5, '02	3	36.54	38.52	6.16		
		Feb. 13, '03	4	17.71	25.39	6.87		
	E.R.	Mar. 21, '02	3	44.15	42.18	9.82	10.64	59.40
		Mar. 25, '02	3	46.40	43.61	11.25		
		Mar. 27, '02	3	46.26	43.09	10.73		
							9.85	58.61
				53°08′		53°08′		
Below Pole.	W.D.	Sept. 22, '02	3	73″.65	43″.37	15″.73	15″.23	56″.01
		Oct. 1, '02	1	74.48	41.90	14.26		
		Oct. 9, '02	4	77.43	43.07	15.43		
	W.R.	June 27, '02	2	41.85	39.17	11.53	12.81	58.43
		Oct. 18, '02	1	77.12	41.06	13.42		
		Oct. 21, '02	1	77.27	40.72	13.08		
		June 8, '03	1	52.20	54.88	13.40		
	E.D.	June 17, '02	3	37.94	37.88	10.24	11.13	60.11
		Sept. 16, '02	1	67.92	39.29	11.65		
		Nov. 20, '02	3	78.01	39.11	11.47		
		Nov. 21, '02	3	77.86	38.93	11.29		
	E.R.	June 26, '02	3	43.60	41.20	13.56	13.59	57.65
							13.19	58.05
								58.33

Table I.—Absolute Declinations for 1900.0. 1 H. Draconis.

		Date of Obs.	No. of Settings.	Zenith Distance. Year of Obs. Obs.	Zenith Distance. Year of Obs. Jan. 0.0.	Zenith Distance. 1900.0	Zenith Distance. 1900.0 Weighted Mean.	Declination. 1900.0
				39° 28′		39° 49′		81° 46′
Above Pole.	W.D.	Apr. 4, '03	2	37″.78	34″.46	21″.12	21″.12	9″.88
	W.R.	Apr. 24, '02	1	52.50	47.20	18.30	18.13	6.89
		Mar. 21, '03	2	31.57	31.26	17.92		
	E.D.	Apr. 7, '03	2	32.73	28.86	15.52	15.22	3.98
		Apr. 9, '03	2	32.54	28.27	14.93		
	E.R.	Mar. 21, '02	3	47.02	47.32	18.42	18.42	7.18
		Feb. 5, '03	2	19.52	31.98	18.64		
		Feb. 6, '03	3	19.48	31.68	18.34		
		Mar. 2, '03	2	27.17	31.89	18.55		
		Mar. 8, '03	1	28.02	31.17	17.83		
							18.22	6.98
				55° 57′		55° 57′		
Below Pole.	W.D.	June 27, '02	2	38″.11	36″.98	5″.88	6″.43	4″.81
		Oct. 1, '02	1	69.63	38.22	7.12		
	W.R.	Oct. 18, '02	1	71.51	36.00	4.90	4.45	6.79
		Oct. 24, '02	1	71.89	35.03	3.93		
	E.D.	June 17, '02	1	31.88	32.99	1.89	1.32	9.92
		Sept. 15, '02	1	58.59	31.84	0.74		
	E.R.	June 25, '03	2	51.30	51.51	4.85	4.88	6.36
							4.27	6.97
								6.98

Table I. ABSOLUTE DECLINATIONS FOR 1900.0. 30 H. CAMELOP.

		Date of Obs.	No. of Settings.	Zenith Distance.				Declination. 1900.0.
				Year of Obs. Obs.	Year of Obs. Jan. 0.0.	1900.0.		
				40°46′		40°47′		83°3′
							Weighted Mean.	
Above Pole.	W.D.	May 2, ’02	2	44″.53	39″.53	15″.74	16″.10	64″.86
		Mar. 21, ’03	2	19.80	22.13	16.46		
	W.R.	Apr. 15, ’02	3	38.98	36.46	12.67	13.44	62.20
		Mar. 25, ’03	2	17.90	19.10	13.43		
		Mar. 28, ’03	3	19.39	19.78	14.11		
	E.D.	Feb. 26, ’03	3	7.52	16.90	11.23	11.23	59.99
		Apr. 9, ’03	2	19.45	16.90	11.23		
	E.R.	Feb. 24, ’03	1	9.62	19.63	13.96	14.04	62.80
		Apr. 7, ’03	2	21.80	19.70	14.03		
							13.70	62.46
				54°39′		54°39′		
Below Pole.	W.D.	Oct. 4, ’01	2	59″.00	28″.07	9″.96	9″.88	61″.36
		Oct. 6, ’02	1	76.58	45.99	9.78		
	W.R.	Oct. 5, ’01	2	57.31	26.05	7.94	8.15	63.09
		Oct. 7, ’01	2	58.38	26.47	8.36		
		Oct. 21, ’02	3	79.27	44.27	8.06		
	E.D.	Oct. 23, ’01	3	60.04	23.48	5.37	6.11	65.13
		Oct. 25, ’01	2	61.41	24.33	6.22		
		Nov. 21, ’02	2	84.30	43.04	6.83		
	E.R.	Nov. 30, ’01	2	69.02	25.81	7.70	8.28	62.96
		Nov. 20, ’02	2	86.14	45.01	8.80		
							8.10	63.14
								62.80

TABLE I.—ABSOLUTE DECLINATIONS FOR 1900.0. CAMEL. S. 664.

		Date of Obs.	No. of Settings.	Zenith Distance.				Declination. 1900.0.
				Year of Obs.		1900.0.		
				Obs.	Jan. 0.0.			
				43° 52′		43° 54′	Weight'd Mean.	86° 10′
Above Pole.	W.D.	Mar. 21, '03	3	68″.56	72″.66	10″.95	11″.28	60″.04
		Mar. 29, '03	3	71.64	73.33	11.62		
	W.R.	Mar. 28, '03	2	69.50	71.49	9.78	9.56	58.32
		Mar. 31, '03	3	69.88	70.99	9.28		
	E.D.	Feb. 6, '03	3	50.59	67.86	6.15	5.90	54.66
		Feb. 26, '03	3	55.93	67.35	5.64		
	E.R.	Feb. 21, '03	2	57.25	70.22	8.51	9.33	58.09
		Feb. 25, '03	2	59.85	71.58	9.87		
		Mar. 2, '03	3	61.02	71.18	9.47		
							9.02	[57.78]

TABLE I.—ABSOLUTE DECLINATIONS FOR 1900.0.

URS. MIN. 3 HS.

		Date of Obs.	No. of Settings.	Zenith Distance.				Declination. 1900.0
				Year of Obs. Obs.	Year of Obs. Jan. 0.0.	1900.0	Weighted Mean.	
				45° 57′		45° 58′		88° 15′
Above Pole.	W.D.	Apr. 11, '02	5	47″.28	49″.98	29″.87	29″.50	18″.26
		Apr. 24, '02	1	49.85	48.92	28.81		
		Mar. 28, '03	3	24.80	29.76	29.60		
	W.R.	Apr. 10, '02	6	43.16	46.15	26.04	25.90	14.66
		Apr. 15, '02	3	44.25	45.78	25.67		
	E.D.	May 13, '02	1	48.03	42.91	22.80	23.15	11.91
		May 22, '02	2	49.64	43.13	23.02		
		May 25, '02	3	50.20	43.34	23.23		
		Feb. 6, '03	4	4.41	23.58	23.42		
	E.R.	May 24, '02	3	53.39	46.64	26.53	26.73	15.49
		Feb. 25, '03	3	12.09	26.65	26.49		
		Mar. 2, '03	2	14.10	27.24	27.08		
							26.32	15.08
				49° 28′		49° 27′		
Below Pole.	W.D.	Dec. 11, '01	1	62″.29	19″.56	59″.61	59″.93	11″.31
		Jan. 8, '02	3	64.89	40.27	60.38		
		Oct. 1, '02	4	58.42	39.60	59.71		
	W.R.	Oct. 20, '02	3	61.88	35.92	56.03	56.47	14.77
		Oct. 24, '02	2	64.19	36.79	56.90		
	E.D.	Oct. 28, '01	3	44.49	13.56	53.61	53.62	17.62
		Nov. 18, '01	1	50.91	13.34	53.39		
		Nov. 24, '02	2	70.72	33.69	53.80		
	E.R.	Oct. 22, '01	1	46.08	17.27	57.32	57.38	13.86
		Oct. 29, '01	1	49.72	18.44	58.49		
		Nov. 9, '01	1	52.13	17.22	57.27		
		Nov. 12, '02	1	70.59	36.89	57.00		
		Nov. 19, '02	3	72.82	37.11	57.22		
		Nov. 21, '02	2	73.09	36.84	56.95		
							56.85	14.39
								14.74

TABLE I.—ABSOLUTE DECLINATIONS FOR 1900.0. 32 H. CAMEL. pr.

		Date of Obs.	No. of Settings.	Zenith Distance.				Declination. 1900.0.
				Year of Obs.		1900.0.		
				Obs.	Jan. 0.0.			
				41 39′		41 40′		83 57′
							Weighted Mean.	
Above Pole.	W.D.	Apr. 11, '02	3	71″.55	76″.32	55″.50	54″.77	43″.53
		Mar. 21, '03	3	46.73	55.91	54.69		
		Mar. 29, '03	1	48.46	55.10	53.88		
	W.R.	Apr. 29, '02	2	73.93	73.35	52.53	52.06	40.82
		Mar. 25, '03	2	44.81	52.72	51.50		
	E.D.	May 16, '02	1	74.68	70.00	49.18	49.30	38.06
		May 22, '02	3	75.50	69.66	48.84		
		Mar. 1, '03	2	36.09	51.13	49.91		
	E.R.	Feb. 6, '03	3	33.63	53.55	52.33	53.21	41.97
		Feb. 25, '03	1	38.63	54.69	53.47		
		Apr. 28, '03	2	57.68	55.08	53.86		
							52.34	41.10
				53 45′		53 45′		
Below Pole.	W.D.	Jan. 8, '02	2	96″.23	72″.28	33″.10	33″.04	38″.20
		Oct. 8, '02	4	88.81	72.17	32.99		
	W.R.	Oct. 24, '02	3	91.51	68.59	29.41	29.49	41.75
		Dec. 18, '02	3	107.66	68.68	29.50		
	E.D.	Nov. 12, '02	3	96.45	66.94	27.76	27.82	43.42
		Nov. 28, '02	3	101.51	67.07	27.89		
	E.R.	Dec. 2, '01	2	88.73	50.87	31.28	30.72	40.52
		Nov. 19, '02	3	101.13	69.34	30.16		
							30.27	40.97
								41.03

TABLE I.—ABSOLUTE DECLINATIONS FOR 1900.0. 32 H. CAMEL. seq.

		Date of Obs.	No. of Settings.	Zenith Distance. Year of Obs. Obs.	Zenith Distance. Year of Obs. Jan. 0.0.	Zenith Distance. 1900.0	Zenith Distance. 1900.0 Weighted Mean.	Declination. 1900.0
				41 39′		41 40′		83 57′
Above Pole.	W.D.	Apr. 24, '02	3	57″.45	56″.62	35″.80	36″.31	25″.07
		Apr. 28, '02	2	58.31	58.01	37.19		
		Mar. 29, '03	2	30.60	37.25	36.01		
	W.R.	June 3, '02	2	62.90	55.27	34.45	33.78	22.54
		June 8, '02	3	62.08	53.93	33.11		
	E.D.	May 9, '02	1	55.61	52.46	31.64	31.55	20.31
		May 13, '02	3	56.03	51.99	31.17		
		Mar. 1, '03	1	18.16	33.21	31.97		
	E.R.	May 25, '02	1	61.88	55.53	34.72	35.27	24.03
		Feb. 24, '03	2	19.24	35.55	34.31		
		Mar. 2, '03	2	22.32	37.10	35.86		
		Apr. 28, '03	1	39.92	37.33	36.09		
							34.23	22.99
				53 46′		53 45′		
Below Pole.	W.D.	Oct. 9, '02	2	46″.76	29″.76	50″.58	50″.46	20″.78
		Oct. 30, '02	3	54.05	29.14	49.96		
		Oct. 31, '02	3	55.30	30.02	50.84		
	W.R.	Oct. 7, '02	1	41.87	25.63	46.45	46.48	24.76
		Oct. 21, '02	3	47.21	25.64	46.46		
	E.D.	Nov. 24, '02	3	57.50	24.22	45.04	45.04	26.20
	E.R.	Nov. 21, '02	3	59.97	27.58	48.40	48.43	22.81
							47.60	23.64
								23.31

TABLE I.—ABSOLUTE DECLINATIONS FOR 1900.0. CEPHEI 135 HS.

		Date of Obs.	No. of Settings.	Zenith Distance.				Declination 1900.0.
				Year of Obs. Obs.	Year of Obs. Jan. 0.0.	1900.0.	1900.0.	
				40°57′		40°58′	Weighted Mean.	83°15′
Above Pole.	W.D.	Apr. 28, '02	1	50″.85	52″.51	28″.55	28″.80	17″.56
		June 8, '02	1	61.56	53.07	29.11		
		Mar. 25, '03	2	24.70	34.69	28.75		
	W.R.	Apr. 29, '02	2	48.63	49.99	26.03	26.20	14.96
		June 3, '02	3	57.87	50.27	26.31		
	E.D.	May 9, '02	2	48.49	46.89	22.93	23.54	12.30
		May 13, '02	3	50.19	47.48	23.52		
		May 16, '02	1	51.82	48.30	24.34		
	E.R.	May 25, '02	3	56.28	50.56	26.60	26.42	15.18
		Feb. 25, '03	3	15.07	32.11	26.17		
							26.24	15.00
				54°28′		54°27′		
Below Pole.	W.D.	Jan. 8, '02	1	55″.52	34″.00	57″.96	58″.38	12″.86
		Oct. 8, '02	4	43.73	35.14	59.10		
		Oct. 9, '02	3	42.94	33.98	57.94		
	W.R.	Dec. 6, '01	1	46.80	14.35	56.33	56.17	15.07
		Oct. 21, '02	2	45.40	31.93	55.89		
		Dec. 18, '02	2	65.39	32.29	56.25		
	E.D.	Nov. 12, '02	1	51.64	29.88	53.84	53.93	17.31
		Nov. 21, '02	2	55.74	30.75	54.71		
		Nov. 24, '02	2	55.38	29.35	53.31		
		Nov. 28, '02	2	57.24	29.89	53.85		
	E.R.	Nov. 19, '02	2	56.84	32.55	56.51	56.54	14.70
							56.26	14.98
								14.99

TABLE I.—ABSOLUTE DECLINATIONS FOR 1900.0. URS. MINORIS 57 B.

		Date of Obs.	No. of Settings.	Zenith Distance.				Declination. 1900.0.
				Year of Obs.		1900.0.		
				Obs.	Jan. 0.0.			
				45 19′		45 20′		87 37′
							Weigh'ted Mean.	
Above Pole.	W.D.	May 2, '02	5	47″.94	50″.48	17″.65		″
		June 13, '02	2	60.13	50.67	17.84	17″.21	5.97
		Mar. 21, '03	4	23.18	35.43	16.19		
	W.R.	Apr. 29, '02	3	42.91	46.41	13.58	13.99	2.75
		June 8, '02	4	55.40	47.13	14.30		
	E.D.	May 8, '02	3	43.53	44.17	11.34		
		May 13, '02	5	45.54	44.61	11.78	11.97	0.73
		Apr. 27, '03	4	30.23	32.01	12.77		
	E.R.	May 25, '02	3	53.49	48.95	16.12	15.84	4.60
		June 26, '02	2	60.34	48.28	15.45		
							14.75	3.51
				50 06′		50 06′		
Below Pole.	W.D.	Oct. 28, '02	3	40″.73	37″.54	10″.37		
		Oct. 30, '02	5	42.15	38.25	11.08	10″.57	0″.67
		Oct. 31, '02	5	41.67	37.41	10.24		
	W.R.	Jan. 22, '02	2	52.18	34.18	7.01		
		Dec. 18, '02	2	55.76	34.67	7.50	7.07	4.17
		Jan. 23, '03	3	62.29	46.71	5.95		
		Jan. 26, '03	1	64.69	48.77	8.01		
	E.D.	Nov. 21, '02	3	44.81	32.93	5.76	5.75	5.49
		Nov. 24, '02	5	45.86	32.90	5.73		
	E.R.	Nov. 19, '02	4	45.98	34.83	7.66	7.69	3.55
							7.77	3.47
								3.49

TABLE I. — ABSOLUTE DECLINATIONS FOR 1900.0. URS. MIN. 33 HS.

		Date of Obs.	No of Settings.	Zenith Distance. Year of Obs. Obs.	Zenith Distance. Year of Obs. Jan. 0.0	Zenith Distance. 1900.0.	Zenith Distance. 1900.0. Weight'd Mean.	Declination 1900.0.
				40° 57′		40° 58′		83° 14′
Above Pole.	W.D.	June 13, '02	5	59″.64	50″.81	11.81	11″.67	60″.43
		June 14, '02	2	59.61	50.51	11.51		
	W.R.	Apr. 29, '02	2	42.06	47.28	8.28	8.72	57.48
		June 8, '02	3	55.44	48.04	9.04		
	E.D.	May 8, '02	2	40.73	43.07	4.07	5.41	54.17
		May 13, '02	3	44.10	44.81	5.81		
		Apr. 9, '03	3	25.85	34.71	6.23		
	E.R.	May 22, '02	1	51.55	49.36	10.36	9.74	58.50
		May 25, '02	1	52.64	49.49	10.49		
		June 26, '02	3	60.43	48.30	9.30		
		Apr. 27, '03	3	33.87	37.54	9.06		
							8.88	57.64 wt. 2.
				54° 28′		54° 28′		
Below Pole.	W.D.	Oct. 28, '02	2	32″.04	36″.87	15″.87	15″.56	55.68
		Oct. 30, '02	3	32.11	36.29	15.29		
	W.R.							
	E.D.	Nov. 24, '02	1	37.82	33.22	12.22	11.56	59.68
		Feb. 5, '03	3	57.83	43.23	11.71		
		Feb. 13, '03	3	57.72	42.45	10.93		
	E.R.							
								57.68 —.10*
								[57.58] wt. 1.
								[57.62]

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* Sine flexure.

TABLE I. — ABSOLUTE DECLINATIONS FOR 1900.0. ε URSÆ MINORIS.

		Date of Obs.	No. of Settings.	Zenith Distance.				Declination 1900.0.
				Years of Obs.		1900.0.		
				Obs.	Jan. 0.0.		Weighted Mean.	
				39°54′		39°55′		82°12′
Above Pole.	W.D.	June 4, '03	1	70.24″	63.94″	20.52″	20.90″	9.66″
		June 9, '03	2	72.70	64.62	21.20		
	W.R.	June 8, '03	2	70.11	62.37	18.95	19.13	7.89
		June 14, '03	1	72.20	62.67	19.25		
	E.D.	May 8, '02	1	59.71	63.71	14.75	15.10	3.86
		May 22, '02	3	64.79	64.32	15.36		
	E.R.	May 21, '02	1	68.82	68.70	19.74	19.29	8.05
		May 11, '03	2	61.15	62.47	19.05		
		Apr. 27, '03	2	57.02	62.48	19.06		
							18.60	7.36 wt. 3
				55°31′		55°31′		
Below Pole.	W.D.	Jan. 8, '02	1	21.75″	16.43″	5.39″	5.18″	6.06
		Jan. 23, '03	1	29.01	21.54	4.96		+2.39*
								8.45
	W.R.							
	E.D.							
	E.R.							
								[8.45] wt. 1
								[7.63]

* Cos flexure, sine flexure and absolute term.

TABLE I.—ABSOLUTE DECLINATIONS FOR 1900.0. δ URSÆ MINORIS

		Date of Obs.	No. of Settings.	Zenith Distance.				Declination. 1900.0.
				Year of Obs.		1900.0.		
				Obs.	Jan. 0.0.			
				44°19′		44°19′		86°36′
							Weight'd Mean.	
Above Pole.	W.D.	June 5, '02	3	66″.29	63″.13	62″.31	62″.00	50″.76
		June 9,' 02	5	67.62	63.22	62.40		
		June 4, '03	1	66.46	62.65	61.46		
		June 8, '03	2	68.02	62.80	61.61		
	W.R.	June 4, '03	2	63.93	60.12	58.93	58.87	47.63
		June 8, '03	2	65.14	59.92	58.73		
	E.D.	June 16, '02	3	64.06	57.42	56.60	56.11	44.87
		June 17, '02	3	63.66	56.65	55.83		
		May 11, '03	1	53.78	56.99	55.80		
	E.R.	May 22, '02	1	59.27	60.49	59.67	59.59	48.35
		Apr. 27, '03	3	54.07	60.65	59.46		
							59.14	47.90
				51°06′		51°06′		
Below Pole.	W.D.	Jan. 16, '02	3	24″.40	23″.74	24″.56	24″.56	46.68
	W.R.	Jan. 22, '02	3	24.37	21.96	22.78	22.51	48.73
		Feb. 13, '02	3	29.61	21.35	22.17		
	E.D.	Mar. 4, '02	3	31.65	20.43	21.25	20.97	50.27
		Mar. 5, '02	1	31.03	19.68	20.50		
		Mar. 6, '02	1	31.90	20.42	21.24		
		Feb. 13, '03	4	26.43	19.64	20.83		
	E.R.	Feb. 24, '03	3	31.40	22.63	23.82	23.88	47.36
		Feb. 25, '03	2	31.46	22.49	23.68		
		Mar. 2, '03	1	32.58	22.92	24.11		
							22.98	48.26
								48.08

TABLE I. — ABSOLUTE DECLINATIONS FOR 1900.0. λ URSÆ MINORIS.

		Date of Obs.	No. of Settings.	Zenith Distance.				Delination 1900.0.
				Year of Obs.		1900 0.		
				Obs.	Jan. o.o.			
				46°42′		46°42′		88°59′
							Weight'd Mean.	
Above Pole.	W.D.	Sept. 22, '02	3	74″.63	43″.59	29″.66	30″.35	19″.11
		Oct. 7, '02	1	75.51	42.90	28.97		
		Oct. 8, '02	4	77.83	45.15	31.22		
		Oct. 9, '02	3	77.78	45.04	31.11		
	W.R.	Sept. 26, '02	2	73.36	41.78	27.85	27.69	16.45
		June 8, '03	2	50.22	48.44	27.69		
		June 9, '03	2	50.25	48.15	27.40		
	E.D.	June 26, '02	2	45.31	38.38	24.45	24.02	12.78
		June 25, '03	2	51.44	44.35	23.60		
	E.R.	June 25, '03	2	55.06	47.97	27.22	27.26	16.02
							27.33	16.09
				48°43′		48°43′		
Below Pole.	W.D.	Feb. 15, '02	3	45″.99	44″.18	58.11	58″.22	13.02
		Feb. 22, '02	7	47.78	44.10	58.03		
		Feb. 24, '02	5	48.60	44.40	58.33		
		Mar. 29, '02	3	53.98	44.99	58.92		
		Mar. 21, '03	2	44.62	36.90	57.65		
	W.R.	Mar. 25, '03	3	42.36	34.16	54.91	54.94	16.30
	E.D.	Mar. 24, '02	1	47.65	38.88	52.81	52.80	18.44
		Mar. 25, '02	9	47.96	39.11	53.04		
		Feb. 6, '03	3	30.42	31.94	52.69		
		Feb. 26, '03	3	35.86	31.91	52.66		
	E.R.	Mar. 19, '02	1	49.44	41.30	55.23	55.51	15.73
		Mar. 27, '02	3	51.08	42.15	56.08		
		Feb. 21, '03	3	37.37	31.76	55.51		
		Feb. 24, '03	3	37.66	31.26	55.01		
							55.37	15.87
								15.98

TABLE I.—ABSOLUTE DECLINATIONS FOR 1900.0. CEPHEI 3 HS.

		Date of Obs.	No of Settings.	Zenith Distance.				Declination. 1900.0.
				Year of Obs.		1900.0.		
				Obs.	Jan. 0.0.			
				42°06′		42°05′		84°22′
							Weight'd Mean.	*
Above Pole.	W.D.	June 5, '02	3	12″.41	13″.98	51″.94	52″.02	40″.78
		June 27, '02	3	19.09	14.15	52.11		
	W.R.	Oct. 18, '02	1	48.67	12.19	50.15	49.93	38.69
		Oct. 21, '02	1	48.47	11.73	49.69		
		Oct. 24, '02	1	48.81	11.86	49.82		
	E.D.	June 17, '02	3	10.20	8.40	46.36	46.26	35.02
		Sept. 15, '02	3	38.99	8.21	46.17		
	E.R.	June 26, '02	1	16.39	11.77	49.73	49.77	38.53
							49.50	38.26
				53°20′		53°20′		
Below Pole.	W.D.	Feb. 22, '02	2	12″.74	13″.07	35″.11	35″.44	35.80
		Mar. 29, '02	3	20.88	13.69	35.73		
	W.R.	Feb. 15, '02	2	8.58	11.01	33.05	33.33	37.91
		Apr. 10, '02	3	19.71	11.49	33.53		
	E.D.	Mar. 4, '02	2	11.03	8.63	30.67	30.57	40.67
		Mar. 5, '02	3	11.09	8.44	30.48		
	E.R.	Mar. 19, '02	2	17.56	11.89	33.93	33.82	37.42
		Mar. 8, '03	3	3.88	0.62	33.66		
							33.29	37.95
								38.10

TABLE I. — ABSOLUTE DECLINATIONS FOR 1900.0. 76 DRACONIS.

		Date of Obs.	No. of Settings.	Zenith Distance.				Declination 1900.0.
				Year of Obs.		1900.00.		
				Obs.	Jan. 0 0.			
				39°53′		39°52′	Weight'd Mean.	82°09′
Above Pole.	W.D.	Sept. 26, '02	3	54″.29	20″.96	53″.87	53″.78	42″.54
		Oct. 6, '02	1	56.11	20.58	53.49		
		Oct. 20, '02	1	58.95	21.03	53.94		
	W.R.	Oct. 10, '01	2	40.99	4.78	51.23	51.11	39.87
		Oct. 7, '02	1	53.73	17.97	50.88		
	E.D.	Oct. 28, '01	2	39.80	1.00	47.45	48.11	36.87
		Sept. 16, '02	1	46.58	16.02	48.93		
	E.R.	Oct. 29, '01	2	46.45	7.51	53.96	53.23	41.99
		Oct. 30, '01	1	44.84	5.78	52.23		
							51.56	40.32
				55°32′		55°33′		
Below Pole.	W.D.	Apr. 11, '02	3	73″.42	66″.18	33″.27	33″.31	37.93
		Apr. 4, '03	2	59.48	52.72	33.34		
	W.R.	Apr. 10, '02	3	71.56	64.36	31.45	31.01	40.23
		Mar. 21, '03	1	54.04	49.72	30.34		
	E.D.	Apr. 7, '03	1	54.50	47.31	27.93	28.33	42.91
		Apr. 9, '03	2	55.50	48.03	28.65		
	E.R.	Feb. 5, '03	1	41.69	50.11	30.73	30.71	40.53
		Feb. 6, '03	1	41.87	50.00	30.62		
							30.84	40.40
								40.36

TABLE I. — ABSOLUTE DECLINATIONS FOR 1900.0. CEPHEI GR. 3548.

		Date of Obs.	No. of Settings.	Zenith Distance.				Declination. 1900.0
				Year of Obs. Obs.	Year of Obs. Jan. 0.0	1900.0		
				44°20′		44°20′	Weighted Mean.	86°37′
Above Pole.	W.D.	Sept. 22, '02	5	100″.38	69″.58	38″.88	39″.16	27″.92
		Oct. 8, '02	5	105.23	70.14	39.44		
	W.R.	Oct. 10, '01	2	86.79	50.91	35.56	35.71	24.47
		Sept. 26, '02	3	98.42	66.46	35.76		
	E.D.	Oct. 23, '01	3	86.57	48.05	32.70	33.04	21.80
		Oct. 28, '01	3	87.28	47.97	32.62		
		Nov. 21, '02	3	105.40	64.51	33.81		
	E.R.	Oct. 24, '01	3	90.39	51.70	36.35	36.22	24.98
		Oct. 30, '01	1	91.08	51.47	36.12		
		June 26, '02	3	67.97	66.76	36.06		
							36.03	24.79
				51°04′		51°05′		
Below Pole.	W.D.	Mar. 29, '02	3	81″.79	78″.29	48″.99	49″.22	22.02
		Apr. 11, '02	3	84.44	78.76	49.46		
	W.R.	Apr. 10, '02	3	81.82	76.27	46.97	47.03	24.21
		Apr. 15, '02	2	82.50	76.34	47.04		
	E.D.	Mar. 4, '02	1	69.97	72.85	43.55	43.71	27.53
		Mar. 5, '02	3	70.48	73.06	43.76		
		Feb. 13, '03	4	49.35	57.73	43.76		
	E.R.	Mar. 19, '02	2	77.72	76.47	47.17	47.04	24.20
		Mar. 25, '02	2	79.60	76.95	47.65		
		Feb. 24, '03	3	55.44	60.25	46.28		
							46.75	24.49
								24.64

TABLE I. — ABSOLUTE DECLINATIONS FOR 1900.0. 32 H. CEPHEI.

		Date of Obs.	No. of Settings.	Zenith Distance.				Declination 1900.0.
				Year of Obs. Obs.	Year of Obs. Jan. 0.0.	1900.0.	1900.0. Weight'd Mean.	
				43°19′		43°19′		85°36′
Above Pole.	W.D.	Sept. 22, '02	3	94″.55	67″.13	30″.60	30″.91	19″.67
		Oct. 1, '02	5	98.20	67.72	31.19		
	W.R.	Oct. 10, '01	2	81.06	46.73	28.46	28.67	17.43
		Oct. 24, '02	3	102.48	65.32	28.79		
	E.D.	Oct. 28, '01	3	83.21	44.05	25.78	25.18	13.94
		June 26, '02	2	59.28	61.31	24.78		
		Sept. 15, '02	1	86.32	61.36	24.83		
	E.R.	Oct. 30, '01	3	87.66	48.05	29.78	29.51	18.27
		June 26, '02	2	63.63	65.66	29.13		
							28.57	17.33
				52°05′		52°06′		
Below Pole.	W.D.	Mar. 29, '02	3	80″.26	80″.09	56″.62	56″.25	14.99
		Apr. 11, '02	3	82.80	79.62	56.15		
		Apr. 28, '02	3	85.31	79.45	55.98		
	W.R.	Apr. 10, '02	3	80.21	77.23	53.76	53.86	17.38
		Apr. 24, '02	3	82.74	77.37	53.90		
	E.D.	Mar. 24, '02	3	73.59	74.76	51.29	51.35	19.89
		May 12, '02	2	81.80	74.99	51.52		
		Feb. 13, '03	4	44.22	56.46	51.25		
	E.R.	Mar. 19, '02	3	75.63	78.23	54.76	54.52	16.72
		Mar. 21, '02	2	76.61	78.63	55.16		
		Feb. 21, '03	2	49.09	58.73	53.52		
							54.00	17.24
								17.29

TABLE I. — ABSOLUTE DECLINATIONS FOR 1900.0.

36 H. CEPHEI.

		Date of Obs.	No. of Settings.	Zenith Distance.				Declination. 1900.0.
				Year of Obs. Obs.	Year of Obs. Jan. 0.0	1900.0.		
				41°32′		41°31′	Weight'd Mean.	83°48′
Above Pole.	W.D.	Oct. 4, '01	3	43″.06	12″.51	53″.24	53″.69	42″.45
		Sept. 22, '02	3	57.57	32.69	54.14		
	W.R.	Oct. 5, '01	1	41.51	10.61	51.34	51.54	40.30
		Oct. 10, '01	2	43.09	10.51	51.24		
		Dec. 6, '01	1	55.30	10.68	51.41		
		Oct. 21, '02	1	64.62	29.99	51.44		
		Oct. 24, '02	3	65.99	30.52	51.97		
	E.D.	Oct. 23, '01	3	44.68	8.07	48.80	48.64	37.40
		Oct. 25, '01	3	44.93	7.76	48.49		
	E.R.	Oct. 22, '01	1	48.85	12.53	53.26	51.96	40.72
		Oct. 24, '01	3	47.60	10.71	51.44		
		Nov. 26, '01	1	55.24	11.52	52.25		
		Nov. 30, '01	3	54.62	10.46	51.19		
							51.46	40.22
				53°53′		53°54′		
Below Pole.	W.D.	Mar. 29, '02	1	52″.12	53″.62	32″.17	33″.67	37.57
		Apr. 28, '02	3	60.65	55.51	34.06		
		May 2, '02	3	61.50	55.82	34.37		
	W.R.	Apr. 10, '02	3	53.72	52.10	30.65	30.75	40.49
		Apr. 15, '02	3	55.00	52.24	30.79		
	E.D.	May 12, '02	3	57.60	50.94	29.49	29.32	41.92
		May 16, '02	2	57.17	50.29	28.84		
		May 17, '02	3	57.95	51.02	29.57		
	E.R.	Feb. 13, '03	3	20.33	34.13	31.95	31.83	39.41
		Feb. 24, '03	3	23.49	33.83	31.65		
							31.39	39.85
								40.04

TABLE I. — ABSOLUTE DECLINATIONS FOR 1900.0. 39 H. CEPHEI.

		Date of Obs.	No. of Settings.	Zenith Distance. Year of Obs. Obs.	Zenith Distance. Year of Obs. Jan. 0.0.	Zenith Distance. 1900.0.	Weight'd Mean.	Declination 1900.0.
				44° 28′		44° 28′		86° 45′
Above Pole.	W.D.	Oct. 4, '01	3	82″.65	55″.14	35″.27	35″.39	24″.15
		Dec. 11, '01	1	100.12	55.47	35.60		
		Sept. 22, '02	3	96.41	75.07	35.33		
	W.R.	Oct. 5, '01	2	80.01	52.13	32.26	32″.28	21.04
		Oct. 7, '01	1	81.27	52.67	32.80		
		Dec. 6, '01	3	95.83	51.70	31.83		
	E.D.	Oct. 23, '01	3	83.89	49.80	29.93	29.45	18.21
		Oct. 25, '01	3	83.57	48.84	28.97		
	E.R.	Oct. 22, '01	2	87.12	53.34	33.47	32.92	21.68
		Oct. 24, '01	1	87.26	52.84	32.97		
		Nov. 9, '01	2	92.14	53.11	33.24		
		Nov. 30, '01	1	95.37	52.02	32.15		
		Nov. 21, '02	3	112.26	72.20	32.46		
							32.51	21.27
				50° 56′		50° 57′		
Below Pole.	W.D.	Apr. 11, '02	1	73″.35	73″.31	53″.05	53″.09	18.15
		Apr. 28, '02	3	77.65	73.71	53.45		
		May 2, '02	1	77.54	72.88	52.62		
	W.R.	Apr. 10, '02	3	69.70	69.92	49.66	49.69	21.55
		Apr. 24, '02	2	73.05	69.91	49.65		
	E.D.	May 12, '02	3	74.15	68.05	47.79	47.94	23.30
		May 16, '02	5	74.95	68.44	48.18		
		May 24, '02	2	75.18	68.10	47.84		
	E.R.	May 9, '02	3	75.89	70.16	49.90	50.38	20.86
		May 17, '02	1	77.79	71.18	50.92		
		Feb. 6, '03	4	33.10	50.57	50.19		
		Feb. 24, '03	4	38.59	50.93	50.55		
							50.27	20.97
								21.12

TABLE I.—ABSOLUTE DECLINATIONS FOR 1900.0. CEPHEI 125 HS.

		Date of Obs.	No. of Settings.	Zenith Distance.				Declination 1900 0.
				Year of Obs. Obs.	Jan. 0.0.	1900.0		
				40°21′		40°21′	Weight'd Mean.	82°38′
Above Pole.	W.D.	Oct. 1, '02	3	80″.45	57″.76	17″.65	18″.07	6″.83
		Oct. 6, '02	1	82.78	58.23	18.12		
		Oct. 7, '02	3	83.47	58.55	18.44		
	W.R.	Oct. 5, '01	3	60.38	34.28	14.23	14.65	3.41
		Dec. 5, '01	1	77.91	34.79	14.74		
		Dec. 6, '01	1	78.34	35.08	15.03		
	E.D.	Oct. 28, '01	2	66.04	31.96	11.91	12.43	1.19
		Nov. 18, '01	2	72.33	32.40	12.35		
		Nov. 20, '02	3	91.25	52.81	12.70		
		Nov. 21, '02	3	91.43	52.79	12.68		
	E.R.	Oct. 22, '01	2	68.23	36.10	16.05	16.16	4.92
		Oct. 29, '01	2	71.57	37.17	17.12		
		Nov. 19, '02	3	93.59	55.39	15.28		
							15.33	4.09
				55°03′		55°05′		
Below Pole.	W.D.	Apr. 11, '02	2	87″.56	88″.13	8″.24	8″.52	2″.72
		Apr. 28, '02	2	93.01	89.44	9.55		
		Mar. 21, '03	2	62.70	67.60	7.76		
	W.R.	Apr. 10, '02	1	86.40	87.23	7.34	7.30	3.94
		Apr. 15, '02	2	87.20	86.69	6.80		
		Mar. 25, '03	2	63.81	67.53	7.69		
	E.D.	May 9, '02	1	90.90	85.33	5.44	5.03	6.21
		May 12, '02	1	90.77	84.77	4.88		
		May 16, '02	3	91.47	84.96	5.07		
		May 17, '02	1	90.61	84.00	4.11		
		May 24, '02	3	92.59	85.34	5.45		
	E.R.	Feb. 13, '03	2	51.86	67.76	7.92	8.09	3.15
		Mar. 2, '03	2	57.10	68.05	8.21		
							7.23	4.01
								4.05

TABLE II. — DECLINATIONS FOR 1900.0 FROM COMPARISON WITH ZERO STARS. CEPHEI BR. 256, 6.9 MAG., R.A. 2h 1m 25s.

		Date.	Zero Star.	Year of Obs. Jan. 0.0.	1900.0.	Differential Flexure.	δ−1900.0.	
				83°05′	83°05′		83°05′	
Above Pole.	W.D.	Oct. 8, '02	λ Urs. min.	63″.42	28″.94	−.13	28″.81	Mean.
		Oct. 8, '02	Polaris.	63.65	29.17	−.13	29.04	
		Oct. 28, '02	Polaris.	65.07	30.59	−.13	30.46	29″.21
		Oct. 28, '02	Gr. 750.	62.64	28.16	−.05	28.11	
		Oct. 29, '02	Polaris.	64.22	29.74	−.13	29.61	
	W.R.	Jan. 22, '02	Gr. 750.	64.97	30.49	−.04	30.45	
		Jan. 22, '02	δ Urs. min. s.p.	65.28	30.80	−.21	30.59	
		Oct. 21, '02	30 H. Camel. s.p.	63.36	28.88	−.29	28.59	
		Oct. 21, '02	Polaris.	64.23	29.75	−.11	29.64	29.94
		Oct. 24, '02	1 H. Draconis s.p.	65.27	30.79	−.32	30.47	
		Oct. 24, '02	Polaris.	64.42	29.94	−.11	29.83	
		Jan. 26, '03	Gr. 750.	81.74	30.02	−.04	29.98	
	E.D.	Nov. 24, '02	Polaris.	63.93	29.45	+.11	29.56	
		Nov. 24, '02	Gr. 750.	62.71	28.23	+.04	28.27	29.01
		Nov. 28, '02	Polaris.	63.58	29.10	+.11	29.21	
	E.R.	Dec. 2, '01	Polaris.	47.35	30.11	+.12	30.23	
		Nov. 19, '02	Polaris.	64.86	30.38	+.12	30.50	
		Nov. 21, '02	Polaris.	65.25	30.77	+.12	30.89	30.32
		Nov. 21, '02	Gr. 750.	64.11	29.63	+.04	29.67	
Below Pole.	W.D.	June 8, '02	Gr. 750. s.p.	64.05	29.57	−.05	29.52	
		June 8, '02	Polaris. s.p.	66.91	32.43	−.14	32.29	
		Mar. 21, '03	λ Urs. min. s.p.	83.85	32.13	−.14	31.99	31.44
		Mar. 21, '03	30 H. Camel.	83.91	32.19	−.32	31.87	
		Mar. 21, '03	Polaris. s.p.	83.40	31.68	−.14	31.54	
	W.R.	Apr. 29, '02	Polaris. s.p.	64.97	30.49	−.13	30.36	
		Apr. 29, '02	Gr. 750. s.p.	64.97	30.49	−.05	30.44	30.34
		June 3, '02	Polaris. s.p.	64.65	30.17	−.13	30.04	
		June 3, '02	Gr. 750. s.p.	65.07	30.59	−.05	30.54	
	E.D.	May 9, '02	Polaris. s.p.	65.10	30.62	+.12	30.74	
		May 9, '02	43 H. Cephei. s.p.	66.56	32.08	+.06	32.14	
		May 13, '02	Polaris. s.p.	64.92	30.44	+.12	30.56	30.98
		May 16, '02	Polaris. s.p.	65.05	30.57	+.12	30.69	
		May 16, '02	43 H. Cephei. s.p.	65.20	30.72	+.06	30.78	
	E.R.	May 25, '02	Polaris. s.p.	64.63	30.15	+.14	30.29	
		Feb. 24, '03	δ Urs. min. s.p.	82.49	30.77	+.09	30.86	
		Feb. 24, '03	λ Urs. min. s.p.	81.37	29.65	+.15	29.80	30.51
		Feb. 24, '03	30 H. Camelop.	81.79	30.07	+.32	30.39	
		Feb. 24, '03	Polaris. s.p.	82.78	31.06	+.14	31.20	
								30.22

TABLE II.—DECLINATIONS FOR 1900.0 FROM COMPARISON WITH ZERO STARS.
CEPHEI 147 HS., 5.9 MAG., R.A. $3^h\ 8^m\ 35^s$.

		Date.	Zero Star.	Year of Obs. Jan. 0.0	1900.0	Diff. Flexure.	δ—1900.0.	
				84°33′ ″	84°33′ ″		84°33′ ″	Mean. ″
Above Pole.	W.D.	Dec. 11, '01	43 H. Cephei	40.07	26.56	— .03	26.53	26.91
		Jan. 8, '02	Polaris	53.69	26.69	— .10	26.59	
		Jan. 8, '02	ε Urs. min. s.p.	54.94	27.94	— .32	27.62	
	W.R.	Dec. 5, '01	43 H. Cephei	40.20	26.69	— .02	26.67	26.67
	E.D.	Nov. 12, '02	Polaris	54.11	27.11	+ .08	27.19	26.51
		Nov. 28, '02	Polaris	53.14	26.14	+ .08	26.22	
		Feb. 5, '03	Polaris	67.29	26.81	+ .08	26.89	
		Feb. 5, '03	Gr. 750	66.20	25.72	+ .01	25.73	
	E.R.							
Below Pole.	W.D.	June 14, '02	Gr. 750 s.p.	53.46	26.46	— .02	26.44	26.34
		Mar. 29, '03	Polaris s.p.	66.85	26.37	— .11	26.26	
		Mar. 29, '03	Gr. 750 s.p.	66.82	26.34	— .02	26.32	
	W.R.	June 3, '02	Polaris s.p.	53.16	26.16	— .09	26.07	26.08
		June 3, '02	Gr. 750 s.p.	53.58	26.58	— .01	26.57	
		Mar. 25, '03	λ Urs. min. s.p.	65.99	25.51	— .09	25.42	
		Mar. 25, '03	30 H. Camel.	65.76	25.28	— .25	25.03	
		Mar. 25, '03	Polaris s.p.	66.71	26.23	— .09	26.14	
		Mar. 28, '03	30 H. Camel.	66.79	26.31	— .25	26.06	
		Mar. 28, '03	Gr. 750 s.p.	67.76	27.28	— .01	27.27	
	E.D.	May 9, '02	Polaris s.p.	53.07	26.07	+ .09	26.16	27.05
		May 9, '02	43 H. Cephei s.p.	54.53	27.53	+ .03	27.56	
		May 16, '02	Polaris s.p.	53.94	26.94	+ .09	27.03	
		May 16, '02	43 H. Cephei s.p.	54.09	27.09	+ .03	27.12	
		Apr. 9, '03	76 Draconis s.p.	67.75	27.27	— .05	27.22	
		Apr. 9, '03	1 H. Draconis.	67.38	26.90	+ .27	27.17	
		Apr. 9, '03	30 H. Camel.	67.35	26.87	+ .25	27.12	
		Apr. 9, '03	Gr. 750 s.p.	67.45	26.97	+ .02	26.99	
	E.R.	May 21, '02	Gr. 750 s.p.	53.02	26.02	+ .02	26.04	26.55
		May 21, '02	ε Urs. min.	54.14	27.14	+ .30	27.44	
		May 22, '02	δ Urs. min.	54.21	27.21	+ .21	27.42	
		June 26, '02	Gr. 750 s.p.	53.47	26.47	+ .02	26.49	
		June 26, '02	51 H. Cephei s.p.	52.93	25.93	+ .06	25.99	
		Apr. 28, '03	Polaris s.p.	66.31	25.83	+ .10	25.93	
								26.59

TABLE II.—DECLINATIONS FOR 1900.0 FROM COMPARISON WITH ZERO STARS.
CEPHEI 149 HS., 5.9 MAG., R.A. $3^h\ 33^m\ 55^s$.

		Date.	Zero Star.		Year of Obs. Jan 0 0.	1900.0.	Diff. Flexure.	δ—1900.0.	
					86° 20′	86° 19′		86° 19′	
									Mean.
Above Pole.	W.D.	Dec. 11, '01	43 H. Cephei		8″.53	56″.67	+ .01	56″.68	
		Jan. 8, '02	Polaris		20.13	56.44	— .06	56.38	56″.82
		Jan. 8, '02	ε Urs. min.	s.p.	21.38	57.69	— .28	57.41	
	W.R.	Jan. 22, '02	Gr. 750		21.06	57.37	+ .02	57.39	
		Jan. 22, '02	δ Urs. min.	s.p.	21.37	57.68	— .15	57.53	56.40
		Feb. 15, '02	Gr. 750		19.01	55.32	+ .02	55.34	
		Feb. 15, '02	51 H. Cephei		19.05	55.36	— .02	55.34	
	E.D.	Nov. 24, '02	Polaris		22.77	59.08	+ .05	59.13	[58.48]*
		Nov. 24, '02	Gr. 750		21.55	57.86	— .02	57.84	
	E.R.	Nov. 19, '02	Polaris		20.75	57.06	+ .05	57.11	
		Nov. 21, '02	Polaris		20.96	57.27	+ .05	57.32	56.84
		Nov. 21, '02	Gr. 750		19.82	56.13	— .03	56.10	
Below Pole.	W.D.	June 8, '02	Polaris	s.p.	21.48	57.79	— .06	57.73	
		June 8, '02	Gr. 750	s.p.	18.62	54.93	+ .03	54.96	
		June 13, '02	Gr. 750	s.p.	19.13	55.44	+ .03	55.47	56.37
		June 13, '02	51 H. Cephei	s.p.	21.25	57.56	— .02	57.54	
		June 14, '02	Gr. 750	s.p.	19.83	56.14	+ .03	56.17	
	W.R.	Apr. 29, '02	Gr. 750	s.p.	20.85	57.16	+ .03	57.19	
		Apr. 29, '02	Polaris	s.p.	20.85	57.16	— .05	57.11	57.06
		June 3, '02	Polaris	s.p.	20.47	56.78	— .05	56.73	
		June 3, '02	Gr. 750	s.p.	20.89	57.20	+ .03	57.23	
	E.D.	May 8, '02	Gr. 750	s.p.	20.37	56.68	— .02	56.66	
		May 8, '02	ε Urs. min.		21.41	57.72	+ .23	57.95	57.48
		May 13, '02	Polaris	s.p.	21.53	57.84	+ .05	57.89	
		May 25, '02	Gr. 750	s.p.	21.14	57.45	— .02	57.43	
	E.R.	May 21, '02	Gr. 750	s.p.	20.15	56.46	— .02	56.44	
		May 21, '02	ε Urs. min.		21.27	57.58	+ .26	57.84	57.04
		May 22, '02	δ Urs. min.		20.36	56.67	+ .17	56.84	
									56.86

*This value was discarded in obtaining the final mean. Probably there is an error in the original record.

TABLE II. — DECLINATIONS FOR 1000.0 FROM COMPARISON WITH ZERO STARS.

CEPHEI 157 HS., 6.3 MAG., R.A. $4^h\ 56^m\ 18^s$.

		Date.	Zero Star.		Year of Obs. Jan. 0.0.	1900.0.	Diff. Flexure.	δ—1900.0.	
					85°49′	85°49′		85°49′	Mean.
Above Pole.	W.D.	Feb. 22, '02	λ Urs. min.	s.p.	58″.24	47″.45	— .12	47″.33	
		Feb. 24, '02	λ Urs. min.	s.p.	57.55	46.76	— .12	46.64	46″.98
	W.R.	Feb. 13, '02	δ Urs. min.	s.p.	58.01	47.22	— .16	47.06	
		Feb. 15, '02	Gr. 750		56.85	46.06	+ .01	46.07	46.40
		Feb. 15, '02	51 H. Cephei		56.89	46.10	— .03	46.07	
	E.D.	Mar. 5, '02	δ Urs. min.	s.p.	57.80	47.01	+ .15	47.16	
		Mar. 5, '02	51 H. Cephei		57.45	46.66	+ .03	46.69	
		Mar. 6, '02	δ Urs. min.	s.p.	56.34	45.55	+ .15	45.70	46.31
		Feb. 5, '03	Polaris		62.66	46.52	+ .06	46.58	
		Feb. 5, '03	Gr. 750		61.57	45.43	— .01	45.42	
	E.R.	Feb. 24, '03	δ Urs. min.	s.p.	61.90	45.76	+ .17	45.93	
		Feb. 24, '03	λ Urs. min.	s.p.	62.80	46.66	+ .11	46.77	
		Feb. 24, '03	30 H. Camel		62.60	46.46	— .06	46.40	46.01
		Feb. 24, '03	Polaris	s.p.	61.61	45.47	+ .12	45.59	
		Feb. 26, '03	51 H. Cephei		61.47	45.33	+ .03	45.36	
Below Pole.	W.D.	June 9, '02	δ Urs. min.		58.01	47.22	— .17	47.05	
		June 13, '02	Gr. 750	s.p.	55.97	45.18	+ .02	45.20	
		June 13, '02	51 H. Cephei	s.p.	58.09	47.30	— .03	47.27	46.20
		Mar. 29, '03	Polaris	s.p.	61.93	45.79	— .07	45.72	
		Mar. 29, '03	Gr. 750	s.p.	61.90	45.76	+ .02	45.78	
	W.R.	June 3, '02	Polaris	s.p.	56.99	46.20	— .06	46.14	
		June 3, '02	Gr. 750	s.p.	57.41	46.62	+ .02	46.64	
		June 5, '02	Gr. 750	s.p.	57.19	46.40	+ .02	46.42	46.21
		Mar. 28, '03	30 H. Camel.		61.67	45.53	— .22	45.31	
		Mar. 28, '03	Gr. 750	s.p.	62.64	46.50	+ .02	46.52	
	E.D.	June 16, '02	δ Urs. min.		56.97	46.18	+ .17	46.35	
		June 17, '02	δ Urs. min.		58.06	47.27	+ .16	47.43	46.92
		June 17, '02	51 H. Cephei	s.p.	57.26	46.47	+ .03	46.50	
		June 17, '02	1 H. Draconis	s.p.	58.26	47.47	— .09	47.38	
	E.R.	June 24, '02	Gr. 750	s.p.	58.33	47.54	— .01	47.53	46.83
		June 26, '02	Gr. 750	s.p.	57.53	46.74	— .01	46.73	
		June 26, '02	51 H. Cephei	s.p.	56.99	46.20	+ .03	46.23	
									46.48

TABLE II.—DECLINATIONS FOR 1900.0 FROM COMPARISON WITH ZERO STARS.
CEPHEI 158 HS., 6.3 MAG., R.A. 5h 29m 55s.

		Date.	Zero Star.		Year of Obs. Jan. 0.0.	1900.0	Diff. Flexure.	δ—1900.0	
					85° 08′	85° 08′		85° 08′	
									Mean.
Above Pole.	W.D.	Jan. 16, '02	δ Urs. min.	s.p.	57″.21	51″.99	— .19	51″.80	
		Feb. 15, '02	λ Urs. min.	s.p.	55.11	49.89	— .13	49.76	50″.85
		Feb. 22, '02	λ Urs. min.	s.p.	56.34	51.12	— .13	50.99	
	W.R.	Jan. 22, '02	δ Urs. min.	s.p.	54.96	49.74	— .17	49.57	
		Jan. 22, '02	Gr. 750		54.65	49.43	.00	49.43	49.67
		Feb. 13, '02	δ Urs. min.	s.p.	55.39	50.17	— .17	50.00	
	E.D.	Mar. 4, '02	δ Urs. min.	s.p.	54.68	49.46	+ .16	49.62	
		Mar. 5, '02	δ Urs. min.	s.p.	56.25	51.03	+ .16	51.19	50.51
		Mar. 5, '02	51 H. Cephei		55.90	50.68	+ .04	50.72	
	E.R.	Mar. 6, '02	51 H. Cephei		54.22	49.00	+ .05	49.05	
		Feb. 24, '03	δ Urs. min.	s.p.	57.73	49.95	+ .19	50.14	
		Feb. 24, '03	λ Urs. min.	s.p.	58.63	50.85	+ .13	50.98	
		Feb. 24, '03	30 H. Camel.		58.43	50.65	— .04	50.61	
		Feb. 24, '03	Polaris	s.p.	57.44	49.66	+ .14	49.80	
		Feb. 25, '03	51 H. Cephei		56.69	48.91	+ .05	48.96	49.91
		Feb. 25, '03	δ Urs. min.	s.p.	58.16	50.38	+ .19	50.57	
		Feb. 25, '03	Polaris	s.p.	57.51	49.73	+ .14	49.87	
		Mar. 2, '03	δ Urs. min.	s.p.	57.75	49.97	+ .19	50.16	
		Mar. 2, '03	51 H. Cephei		56.64	48.86	+ .04	48.90	
		Mar. 2, '03	1 H. Draconis		57.82	50.04	— .07	49.97	
		Mar. 2, '03	Polaris	s.p.	57.59	49.81	+ .14	49.95	
Below Pole.	W.D.	June 5, '02	δ Urs. min.		54.97	49.75	— .19	49.56	
		June 9, '02	δ Urs. min.		56.23	51.01	— .19	50.82	50.00
		Mar. 29, '03	Polaris	s.p.	57.64	49.86	— .09	49.77	
		Mar. 29, '03	Gr. 750	s.p.	57.61	49.83	.00	49.83	
	W.R.	June 3, '02	Polaris	s.p.	56.52	51.30	— .10	51.20	
		June 3, '02	Gr. 750	s.p.	56.94	51.72	— .02	51.70	50.47
		Mar. 28, '03	30 H. Camel.		56.90	49.12	— .24	48.88	
		Mar. 28, '03	Gr. 750	s.p.	57.87	50.09	.00	50.09	
	E.D.	June 16, '02	δ Urs. min.		55.81	50.59	+ .18	50.77	
		June 17, '02	δ Urs. min.		55.83	50.61	+ .18	50.79	50.54
		June 17, '02	51 H. Cephei	s.p.	55.03	49.81	+ .05	49.86	
		June 17, '02	1 H. Draconis	s.p.	56.03	50.81	— .07	50.74	
	E.R.	May 21, '02	Gr. 750	s.p.	53.77	48.55	.00	48.55	
		May 21, '02	ε Urs. min.		54.89	49.67	+ .28	49.95	49.59
		May 22, '02	δ Urs. min.		55.29	50.07	+ .19	50.26	
									50.19

TABLE II.—DECLINATIONS FOR 1900.0 FROM COMPARISON WITH ZERO STARS. CEPHEI 109 HS., 6.2 MAG., R.A. 7ʰ 53ᵐ 2ˢ.

		Date.	Zero Star.	Year of Obs. Jan. 0.0.	1900.0.	Diff. Flexure.	δ—1900.0.	
				84°20′	84°20′		84°20′	
Above Pole.	W.D.	Mar. 29,'02	51 H. Cephei	30″.59	49″.62	—.06	49″.56	Mean.
		Mar. 29,'02	λ Urs. min. s.p.	31.02	50.05	—.15	49.90	49″.92
		Apr. 11,'02	76 Draconis s.p.	32.14	51.17	—.32	50.85	
		Apr. 11,'02	Polaris s.p.	30.48	49.51	—.15	49.36	
	W.R.	Feb. 15,'02	Gr. 750	28.98	48.01	—.01	48.00	
		Feb. 15,'02	51 H. Cephei	29.02	48.05	—.05	48.00	48.78
		Mar. 21,'03	76 Draconis sp.	21.56	50.14	—.28	49.86	
		Mar. 21,'03	1 H. Draconis	20.63	49.21	+.05	49.26	
	E.D.	Mar. 4,'02	δ Urs. min. s.p.	31.09	50.12	+.18	50.30	
		Mar. 5,'02	δ Urs. min. s.p.	30.29	49.32	+.18	49.50	49.61
		Mar. 5,'02	51 H. Cephei	29.94	48.97	+.06	49.03	
	E.R.	Mar. 19,'02	51 H. Cephei	29.89	48.92	+.07	48.99	
		Mar. 19,'02	λ Urs. min. s.p.	32.14	51.17	+.15	51.32	50.47
		Mar. 27,'02	λ Urs. min. s.p.	31.93	50.96	+.15	51.11	
Below Pole.	W.D.	June 5,'02	δ Urs. min.	32.40	51.43	—.21	51.22	49.78
		Oct. 6,'02	76 Draconis	30.53	49.56	—.31	49.25	
		Oct. 6,'02	30 H. Camel. s.p.	29.80	48.83	+.03	48.86	
	W.R.	Oct. 7,'02	76 Draconis	31.21	50.24	—.27	49.97	
		Oct. 18,'02	1 H. Draconis s.p.	30.65	49.68	+.06	49.74	50.04
		Oct. 20,'02	Polaris	29.67	48.70	—.15	48.55	
		June 9,'03	51 H. Cephei s.p.	22.30	50.88	—.06	50.82	
		June 9,'03	λ Urs. min.	22.69	51.27	—.14	51.13	
	E.D.	June 17,'02	δ Urs. min.	30.69	49.72	+.19	49.91	
		June 17,'02	51 H. Cephei s.p.	29.89	48.92	+.06	48.98	49.46
		June 17,'02	1 H. Draconis s.p.	30.89	49.92	—.06	49.86	
		Sept. 15,'02	1 H. Draconis s.p.	30.14	49.17	—.07	49.10	
	E.R.	June 26,'02	Gr. 750 s.p.	29.67	48.70	+.02	48.72	
		June 26,'02	51 H. Cephei s.p.	29.13	48.16	+.06	48.22	48.47
								49.57

TABLE II. — DECLINATIONS FOR 1900.0 FROM COMPARISON WITH ZERO STARS. URSÆ MINORIS 4B, 7.2 MAG., R.A. $7^h\ 58^m\ 3^s$.

		Date.	Zero Star.	Year of Obs. Jan. 0.0.	1900.0.	Diff. Flexure.	δ—1900.0.	
				88°55′	88°55′		88°55′	
				″	″		″	Mean. ″
Above Pole.	W.D.	Mar. 29,'02	51 H. Cephei	39.54	59.42	+.04	59.46	59.29
		Mar. 29,'02	λ Urs. min. s.p.	39.97	59.85	−.05	59.80	
		Mar. 25,'03	51 H. Cephei	28.20	58.14	+.04	58.18	
		Mar. 25,'03	Polaris s.p.	29.84	59.78	−.05	59.73	
	W.R.	Mar. 21,'03	76 Draconis s.p.	30.17	60.11	−.20	59.91	59.60
		Mar. 21,'03	1 H. Draconis	29.24	59.18	+.13	59.31	
		Mar. 25,'03	λ Urs. min. s.p.	29.81	59.75	−.05	59.70	
		Mar. 25,'03	30 H. Camel.	30.04	59.98	+.11	60.09	
		Mar. 25,'03	Polaris s.p.	29.09	59.03	−.05	58.98	
	E.D.	Mar. 24,'02	51 H. Cephei	38.85	58.73	−.03	58.70	59.07
		Mar. 24,'02	λ Urs. min. s.p.	38.47	58.35	+.04	58.39	
		Mar. 25,'02	λ Urs. min. s.p.	39.44	59.32	+.04	59.36	
		Feb. 5,'03	Polaris	29.72	59.66	.00	59.66	
		Feb. 5,'03	Gr. 750	28.63	58.57	−.07	58.50	
		Feb. 6,'03	51 H. Cephei	29.32	59.26	−.03	59.23	
		Feb. 6,'03	λ Urs. min. s.p.	29.67	59.61	+.04	59.65	
	E.R.	Feb. 5,'03	76 Draconis s.p.	30.71	60.65	+.21	60.86	60.01
		Feb. 5,'03	1 H. Draconis	29.45	59.39	−.16	59.23	
		Feb. 24,'03	δ Urs. min. s.p.	29.71	59.65	+.10	59.75	
		Feb. 24,'03	λ Urs. min. s.p.	30.61	60.55	+.04	60.59	
		Feb. 24,'03	30 H. Camel.	30.41	60.35	−.13	60.22	
		Feb. 24,'03	Polaris s.p.	29.42	59.36	+.05	59.41	
Below Pole.	W.D.	June 27,'02	1 H. Draconis s.p.	38.69	58.57	+.18	58.75	58.92
		Sept. 22,'02	λ Urs. min.	39.08	58.96	−.05	58.91	
		Sept. 26,'02	76 Draconis	39.42	59.30	−.20	59.10	
	W.R.	June 27,'02	51 H. Cephei s.p.	39.87	59.75	+.04	59.79	58.61
		June 8,'03	λ Urs. min.	29.05	58.99	−.04	58.95	
		June 8,'03	ε Urs. min.	28.08	58.02	−.17	57.85	
		June 8,'03	δ Urs. min.	28.00	57.94	−.09	57.85	
	E.D.	June 17,'02	δ Urs. min.	39.17	59.05	+.09	59.14	58.81
		June 17,'02	51 H. Cephei s.p.	38.37	58.25	−.04	58.21	
		June 17,'02	1 H. Draconis s.p.	39.37	59.25	−.16	59.09	
	E.R.	June 26,'02	Gr. 750 s.p.	39.21	59.09	−.09	59.00	58.57
		June 26,'02	51 H. Cephei s.p.	38.67	58.55	−.05	58.50	
		June 25,'03	51 H. Cephei s.p.	28.29	58.23	−.05	58.18	
		June 25,'03	1 H. Draconis s.p.	28.73	58.67	−.18	58.49	
		June 25,'03	λ Urs. min.	28.68	58.62	+.04	58.66	
								59.11

TABLE II. — DECLINATIONS FOR 1900.0 FROM COMPARISON WITH ZERO STARS.
CEPHEI 121 HS., 6.3 MAG., R.A. $8^h 54^m 32^s$.

		Date.	Zero Star.	Year of Obs. Jan. 0.0.	1900.0.	Diff. Flexure.	δ — 1900.0.	Mean.
				84 34′	84 34′		84 34′	
Above Pole.	W.D.	Feb. 22,'02	λ Urs. min. s.p.	32″.02	59″.66	—.15	59.51	
		Mar. 29,'02	λ Urs. min. s.p.	30.14	57.78	—.15	57.63	58″.14
		Mar. 29,'02	51 H. Cephei	29.71	57.35	—.06	57.29	
	W.R.	Apr. 15,'02	30 H. Camel.	32.57	60.21	+.03	60.24	
		Mar. 25,'03	λ Urs. min. s.p.	18.29	59.77	—.13	59.64	
		Mar. 25,'03	30 H. Camel.	18.52	60.00	+.03	60.03	
		Mar. 25,'03	Polaris s.p.	17.57	59.05	—.13	58.92	59.24
		Mar. 28,'03	30 H. Camel.	17.39	58.87	+.03	58.90	
		Mar. 28,'03	Gr. 750 s.p.	16.42	57.90	—.21	57.69	
	E.D.	Mar. 4,'02	δ Urs. min. s.p.	29.40	57.04	+.17	57.21	
		Mar. 5,'02	51 H. Cephei	30.15	57.79	+.05	57.84	
		Mar. 5,'02	δ Urs. min. s.p.	30.50	58.14	+.17	58.31	58.66
		Feb. 13,'03	Gr. 750	16.78	58.26	+.01	58.27	
		Feb. 13,'03	δ Urs. min. s.p.	17.04	58.52	+.17	58.69	
	E.R.	Mar. 21,'02	1 H. Draconis	30.75	58.39	—.06	58.33	58.84
		Mar. 27,'02	λ Urs. min. s.p.	31.58	59.22	+.14	59.36	
Below Pole.	W.D.	Sept. 22,'02	λ Urs. min.	30.86	58.50	—.16	58.34	
		Oct. 1,'02	1 H. Draconis s.p.	32.21	59.85	+.07	59.92	59.21
		Oct. 9,'02	λ Urs. min.	32.61	60.25	—.16	60.09	
		Oct. 9,'02	Polaris	31.01	58.65	—.16	58.49	
	W.R.	June 27,'02	51 H. Cephei s.p.	31.52	59.16	—.05	59.11	
		Oct. 18,'02	1 H. Draconis s.p.	30.58	58.22	+.07	58.29	
		Oct. 21,'02	30 H. Camel. s.p.	30.66	58.30	+.04	58.34	58.15
		Oct. 21,'02	Polaris	29.79	57.43	—.14	57.29	
		June 8,'03	ε Urs. min.	16.41	57.89	—.26	57.63	
		June 8,'03	δ Urs. min.	16.33	57.81	—.18	57.63	
		June 8,'03	λ Urs. min.	17.38	58.86	—.13	58.73	
	E.D.	June 17,'02	δ Urs. min.	30.80	58.44	+.19	58.63	
		June 17,'02	51 H. Cephei s.p.	30.00	57.64	+.06	57.70	
		June 17,'02	1 H. Draconis s.p.	31.00	58.64	—.06	58.58	
		Sept. 15,'02	1 H. Draconis s.p.	30.16	57.80	—.06	57.74	58.31
		Sept. 16,'02	76 Draconis	29.99	57.63	+.27	57.90	
		Nov. 21,'02	30 H. Camel s.p.	31.22	58.86	—.03	58.83	
		Nov. 21,'02	Polaris	31.00	58.64	+.14	58.78	
	E.R.	June 26,'02	Gr. 750 s.p.	29.81	57.45	+.02	57.47	57.22
		June 26,'02	51 H. Cephei s.p.	29.27	56.91	+.06	56.97	
								58.40

TABLE II. DECLINATIONS FOR 1900.0 FROM COMPARISON WITH ZERO STARS.
CAMELOP. S 664, 7.4 MAG., R.A. $11^h\ 2^m\ 30^s$.

		Date.	Zero Star.		Year of Obs. Jan. 0 0.	1900.0.	Diff. Flexure.	δ—1900.0.	
					86° 9′	86°10′		86°10′	
Above Pole.	W.D.	Mar. 21, '03	λ Urs. min.	s.p.	59″.58	57″.87	− .11	57″.76	Mean.
		Mar. 21, '03	Polaris	s.p.	60.03	58.32	− .11	58.21	
		Mar. 21, '03	30 H. Camel.		59.52	57.81	+ .07	57.88	58″.33
		Mar. 29, '03	Polaris	s.p.	60.75	59.04	− .11	58.93	
		Mar. 29, '03	Gr. 750	s.p.	60.78	59.07	− .20	58.87	
	W.R.	Mar. 28, '03	30 H. Camel.		60.70	58.99	+ .06	59.05	
		Mar. 28, '03	Gr. 750	s.p.	59.73	58.02	− .18	57.84	58.09
		Mar. 31, '03	43 H. Cephei	s.p.	59.26	57.55	− .17	57.38	
	E.D.	Feb. 6, '03	51 H. Cephei		59.39	57.68	+ .02	57.70	
		Feb. 6, '03	λ Urs. min.	s.p.	59.74	58.03	+ .09	58.12	57.78
		Feb. 26, '03	λ Urs. min.	s.p.	59.26	57.55	+ .09	57.64	
		Feb. 26, '03	30 H. Camel.		59.44	57.73	− .06	57.67	
	E.R.	Feb. 21, '03	λ Urs. min.	s.p.	59.28	57.57	+ .11	57.68	
		Feb. 21, '03	43 H. Cephei	s.p.	59.32	57.61	+ .19	57.80	
		Feb. 25, '03	51 H. Cephei		58.91	57.20	+ .03	57.23	
		Feb. 25, '03	Polaris	s.p.	59.73	58.02	+ .12	58.14	
		Feb. 25, '03	δ Urs. min.	s.p.	60.38	58.67	+ .17	58.84	57.79
		Mar. 2, '03	δ Urs. min.	s.p.	59.55	57.84	+ .17	58.01	
		Mar. 2, '03	51 H. Cephei		58.44	56.73	+ .02	56.75	
		Mar. 2, '03	1 H. Draconis		59.62	57.91	− .09	57.82	
		Mar. 2, '03	Polaris	s.p.	59.39	57.68	+ .12	57.80	
									58.00

TABLE II.—DECLINATIONS FOR 1900.0. FROM COMPARISON WITH ZERO STARS.
URS. MIN., 3 HS., 6.2 MAG., R.A. 12h 14m 23s.

		Date.	Zero Star.	Year of Obs Jan. 0.0.	1900.0.	Diff Flexure.	δ−1900.0.	Mean.
				88° 14′	88° 15′		88° 15′	
Above Pole.	W.D.	Apr. 11, '02	Polaris s.p.	35″.39	15″.28	− .07	15″.21	16″.00
		Apr. 11, '02	76 Draconis s.p.	37.05	16.94	− .24	16.70	
		Apr. 24, '02	Polaris s.p.	35.88	15.77	− .07	15.70	
		Mar. 28, '03	Polaris s.p.	16.62	16.46	− .07	16.39	
	W.R.	Apr. 10, '02	76 Draconis s.p.	35.04	14.93	− .21	14.72	15.57
		Apr. 15, '02	30 H. Camel.	36.43	16.32	+ .10	16.42	
	E.D.	May 13, '02	Polaris s.p.	34.08	13.97	+ .06	14.03	14.93
		May 22, '02	ε Urs. min.	35.43	15.32	− .12	15.20	
		May 25, '02	Gr. 750 s.p.	35.13	15.02	+ .13	15.15	
		Feb. 6, '03	51 H. Cephei	15.11	14.95	− .02	14.93	
		Feb. 6, '03	λ Urs. min. s.p.	15.46	15.30	+ .05	15.35	
	E.R.	Feb. 25, '03	51 H. Cephei	13.98	13.82	− .02	13.80	14.93
		Feb. 25, '03	Polaris s.p.	14.80	14.64	+ .07	14.71	
		Feb. 25, '03	δ Urs. min. s.p.	15.45	15.29	+ .12	15.41	
		Mar. 2, '03	δ Urs. min. s.p.	15.61	15.45	+ .12	15.57	
		Mar. 2, '03	51 H. Cephei	14.50	14.34	− .03	14.31	
		Mar. 2, '03	1 H. Draconis	15.68	15.52	− .14	15.38	
		Mar. 2, '03	Polaris s.p.	15.45	15.29	+ .07	15.36	
Below Pole.	W.D.	Dec. 11, '01	43 H. Cephei	54.54	14.49	− .14	14.35	13.90
		Jan. 8, '02	Polaris	34.03	13.92	− .07	13.85	
		Jan. 8, '02	ε Urs. min. s.p.	32.78	12.67	+ .15	12.82	
		Oct. 1, '02	1 H. Draconis s.p.	34.51	14.40	+ .16	14.56	
	W.R.	Oct. 20, '02	Polaris	33.97	13.86	− .06	13.80	14.15
		Oct. 24, '02	1 H. Draconis s.p.	33.96	13.85	+ .15	14.00	
		Oct. 24, '02	Polaris	34.81	14.70	− .06	14.64	
	E.D.	Oct. 28, '01	76 Draconis	54.23	14.18	+ .19	14.37	14.89
		Nov. 18, '01	43 H. Cephei	54.05	14.00	+ .12	14.12	
		Nov. 24, '02	Polaris	34.94	14.83	+ .06	14.89	
		Nov. 24, '02	Gr. 750	36.16	16.05	+ .13	16.18	
	E.R.	Oct. 22, '01	43 H. Cephei	54.03	13.98	+ .14	14.12	14.42
		Oct. 29, '01	76 Draconis	56.00	15.95	+ .21	16.16	
		Nov. 9, '01	43 H. Cephei	52.99	12.94	+ .14	13.08	
		Nov. 19, '02	Polaris	33.87	13.76	+ .07	13.83	
		Nov. 21, '02	Polaris	34.08	13.97	+ .07	14.04	
		Nov. 21, '02	Gr. 750	35.22	15.11	+ .15	15.26	
								14.85

TABLE II. — DECLINATIONS FOR 1900.0 FROM COMPARISON WITH ZERO STARS.
32 H. CAMELOP. PR., 6.3 MAG., R.A. 12h 48m 16s.

		Date.	Zero Star.		Year of Obs. Jan. 0.0.	1900.0.	Diff Flexure.	δ—1900.0.	
					83°56′	83 57′		83 57′	Mean.
					″	″		″	″
Above Pole.	W.D.	Apr. 11,'02	76 Draconis	s.p.	63.39	42.57	−.33	42.24	41.45
		Apr. 11,'02	Polaris	s.p.	61.73	40.91	−.16	40.75	
		Mar. 21,'03	λ Urs. min.	s.p.	42.83	41.61	−.16	41.45	
		Mar. 21,'03	30 H. Camel.		42.77	41.55	+.02	41.57	
		Mar. 21,'03	Polaris	s.p.	43.28	42.06	−.16	41.90	
		Mar. 29,'03	Polaris	s.p.	42.52	41.30	−.16	41.14	
		Mar. 29,'03	Gr. 750	s.p.	42.55	41.33	−.25	41.08	
	W.R.	Apr. 29,'02	Polaris	s.p.	62.81	41.99	−.14	41.85	41.27
		Apr. 29,'02	Gr. 750	s.p.	62.81	41.99	−.22	41.77	
		Mar. 25,'03	λ Urs. min.	s.p.	42.38	41.16	−.14	41.02	
		Mar. 25,'03	30 H. Camel.		42.61	41.39	+.02	41.41	
		Mar. 25,'03	Polaris	s.p.	41.66	40.44	−.14	40.30	
	E.D.	May 16,'02	Polaris	s.p.	61.18	40.36	+.15	40.51	40.72
		May 16,'02	43 H. Cephei	s.p.	61.03	40.21	+.21	40.42	
		May 22,'02	ε Urs. min.		61.96	41.14	−.03	41.11	
		Mar. 1,'03	Polaris	s.p.	41.92	40.70	+.15	40.85	
	E.R.	Feb. 6,'03	76 Draconis	s.p.	43.27	42.05	+.33	42.38	41.67
		Feb. 6,'03	1 H. Draconis		42.20	40.98	−.04	40.94	
		Feb. 25,'03	51 H. Cephei		42.02	40.80	+.08	40.88	
		Feb. 25,'03	Polaris	s.p.	42.84	41.62	+.17	41.79	
		Feb. 25,'03	δ Urs. min.	s.p.	43.49	42.27	+.22	42.49	
		Apr. 28,'03	Polaris	s.p.	42.61	41.39	+.17	41.56	
Below Pole.	W.D.	Jan. 8,'02	Polaris		62.02	41.20	−.17	41.03	41.44
		Jan. 8,'02	ε Urs. min.	s.p.	60.77	39.95	+.05	40.00	
		Oct. 8,'02	λ Urs. min.		63.62	42.80	−.17	42.63	
		Oct. 8,'02	Polaris		63.09	42.27	−.17	42.10	
	W.R.	Oct. 24,'02	1 H. Draconis	s.p.	62.16	41.34	+.05	41.39	41.58
		Oct. 24,'02	Polaris		63.01	42.19	−.16	42.03	
		Dec. 18,'02	Polaris		62.25	41.43	−.16	41.27	
		Dec. 18,'02	Gr. 750		62.70	41.88	−.23	41.65	
	E.D.	Nov. 12,'02	Polaris		62.31	41.49	+.15	41.64	41.48
		Nov. 28,'02	Polaris		61.98	41.16	+.15	41.31	
	E.R.	Dec. 2,'01	Polaris		80.43	40.02	+.17	40.19	40.60
		Nov. 19,'02	Polaris		61.64	40.82	+.18	41.00	
									41.28

TABLE II.—DECLINATIONS FOR 1900.0 FROM COMPARISON WITH ZERO STARS.
32 H. CAMELOP. SEQ., 5.5 MAG., R.A. 12h 48m 23s.

		Date.	Zero Star.		Year of Obs. Jan. 0.0.	1900.0.	Diff. Flexure.	δ — 1900.0.	Mean.
					83 56′	83 57′		83°57′	
Above Pole.	W.D.	Apr. 24,'02	Polaris	s.p.	43″.58	22″.76	—.16	22″.60	22″.84
		Apr. 28,'02	Polaris	s.p.	43.28	22.46	—.16	22.30	
		Mar. 29,'03	Polaris	s.p.	24.67	23.43	—.16	23.27	
		Mar. 29,'03	Gr. 750	s.p.	24.70	23.46	—.25	23.21	
	W.R.	June 3,'02	Polaris	s.p.	44.74	23.92	—.14	23.78	23.43
		June 3,'02	Gr. 750	s.p.	44.32	23.50	—.22	23.28	
		June 8,'02	Polaris	s.p.	44.18	23.36	—.14	23.22	
	E.D.	May 9,'02	43 H. Cephei	s.p.	42.53	21.71	+.21	21.92	22.66
		May 9,'02	Polaris	s.p.	43.99	23.17	+.15	23.32	
		May 13,'02	Polaris	s.p.	43.16	22.34	+.15	22.49	
		Mar. 1,'03	Polaris	s.p.	24.00	22.76	+.15	22.91	
	E.R.	May 25,'02	Polaris	s.p.	44.36	23.54	+.17	23.71	23.70
		Feb. 24,'03	δ Urs. min.	s.p.	24.21	22.97	+.22	23.19	
		Feb. 24,'03	λ Urs. min.	s.p.	25.11	23.87	+.16	24.03	
		Feb. 24,'03	30 H. Camel.		24.91	23.67	—.01	23.66	
		Feb. 24,'03	Polaris	s.p.	23.92	22.68	+.17	22.51	
		Mar. 2,'03	δ Urs. min.	s.p.	25.47	24.23	+.22	24.45	
		Mar. 2,'03	51 H. Cephei		24.36	23.12	+.07	23.19	
		Mar. 2,'03	1 H. Draconis		25.54	24.30	—.04	24.26	
		Mar. 2,'03	Polaris	s.p.	25.31	24.07	+.17	24.24	
		Apr. 28,'03	Polaris	s.p.	24.86	23.62	+.17	23.79	
Below Pole.	W.D.	Oct. 9,'02	λ Urs. min.		45.92	25.10	—.17	24.93	23.94
		Oct. 9,'02	Polaris		44.32	23.50	—.17	23.33	
		Oct. 30,'02	Polaris		44.72	23.90	—.17	23.73	
		Oct. 30,'02	Gr. 750		45.43	24.61	—.25	24.36	
		Oct. 31,'02	Polaris		44.32	23.50	—.17	23.33	
	W.R.	Oct. 7,'02	76 Draconis		45.59	24.77	—.28	24.49	24.44
		Oct. 21,'02	30 H. Camel.	s.p.	45.74	24.92	+.02	24.94	
		Oct. 21,'02	Polaris		44.87	24.05	—.16	23.89	
	E.D.	Nov. 24,'02	Polaris		44.41	23.59	+.15	23.74	24.38
		Nov. 24,'02	Gr. 750		45.63	24.81	+.22	25.03	
	E.R.	Nov. 21,'02	Polaris		43.34	22.52	+.18	22.70	23.31
		Nov. 21,'02	Gr. 750		44.48	23.66	+.26	23.92	
									23.59

Table II.—Declinations for 1900.0 from comparison with zero stars.
Cephei 135 Hs., 6.1 mag., R.A. $13^h\ 45^m\ 10^s$.

		Date.	Zero Star.		Year of Obs Jan. 0.0.	1900.0	Diff. Flexure.	δ—1900.0.	
					83°14′	83 15′		83 15′	
Above Pole.	W.D.	Apr. 28, '02	Polaris	s.p.	37″.78	13″.82	— .17	13″.65	Mean.
		June 8, '02	Gr. 750	s.p.	41.28	17.32	— .26	17.06	
		June 8, '02	Polaris	s.p.	38.42	14.46	— .17	14.29	14″.90
		Mar. 25, '03	51 H. Cephei		20.00	14.06	— .08	13.98	
		Mar. 25, '03	Polaris	s.p.	21.64	15.70	— .17	15.53	
	W.R.	Apr. 29, '02	Polaris	s.p.	39.45	15.49	— .15	15.34	
		Apr. 29, '02	Gr. 750	s.p.	39.45	15.49	— .23	15.26	
		June 3, '02	Polaris	s.p.	39.74	15.78	— .15	15.63	15.34
		June 3, '02	Gr. 750	s.p.	39.32	15.36	— .23	15.13	
	E.D.	May 9, '02	Polaris	s.p.	38.42	14.46	+ .16	14.62	
		May 9, '02	43 H. Cephei	s.p.	36.96	13.00	+ .22	13.22	
		May 13, '02	Polaris	s.p.	38.65	14.69	+ .16	14.85	14.79
		May 16, '02	43 H. Cephei	s.p.	39.33	15.37	+ .22	15.59	
		May 16, '02	Polaris	s.p.	39.48	15.52	+ .16	15.68	
	E.R.	May 25, '02	Polaris	s.p.	39.39	15.43	+ .18	15.61	
		Feb. 25, '03	51 H. Cephei		19.44	13.50	+ .09	13.59	
		Feb. 25, '03	Polaris	s.p.	20.76	14.82	+ .18	15.00	14.85
		Feb. 25, '03	δ Urs. min.	s.p.	20.91	14.97	+ .23	15.20	
Below Pole.	W.D.	Jan. 8, '02	Polaris		40.30	16.34	— .19	16.15	
		Jan. 8, '02	ε Urs. min.	s.p.	39.05	15.09	+ .03	15.12	
		Oct. 8, '02	λ Urs. min.		40.65	16.69	— .19	16.50	16.26
		Oct. 8, '02	Polaris		40.42	16.46	— .19	16.27	
		Oct. 9, '02	λ Urs. min.		41.70	17.74	— .19	17.55	
		Oct. 9, '02	Polaris		40.10	16.14	— .19	15.95	
	W.R.	Dec. 6, '01	43 H. Cephei		57.27	15.29	— .23	15.06	
		Dec. 6, '01	Polaris		56.04	14.06	— .17	13.89	
		Oct. 21, '02	30 H. Camel.	s.p.	39.45	15.49	+ .01	15.50	14.72
		Oct. 21, '02	Polaris		38.58	14.62	— .17	14.45	
		Dec. 18, '02	Polaris		38.64	14.68	— .17	14.51	
		Dec. 18, '02	Gr. 750		39.09	15.13	— .24	14.89	
	E.D.	Nov. 12, '02	Polaris		39.37	15.41	+ .17	15.58	
		Nov. 21, '02	30 H. Camel.	s.p.	39.40	15.44	.00	15.44	
		Nov. 21, '02	Polaris		39.14	15.18	+ .17	15.35	15.67
		Nov. 24, '02	Polaris		39.28	15.32	+ .17	15.49	
		Nov. 24, '02	Gr. 750		40.50	16.54	+ .24	16.78	
		Nov. 28, '02	Polaris		39.16	15.20	+ .17	15.37	
	E.R.	Nov. 19, '02	Polaris		38.43	14.47	+ .19	14.66	14.66
									15.15

TABLE II. — DECLINATIONS FOR 1900.0 FROM COMPARISON WITH ZERO STARS.
URS. MIN. 57 B, 7.1 MAG., R.A. 15h 9m 21s.

		Date.	Zero Star.	Year of Obs. Jan. 0.0.	1900.0.	Diff. Flexure.	δ—1900.0.	
				87° 36′	87° 37′		87° 37′	Mean.
Above Pole.	W.D.	May 2,'02	30 H. Camel.	38″.06	5″.23	+ .09	5″.32	3″.78
		June 13,'02	Gr. 750 s.p.	37.87	5.04	— .17	4.87	
		June 13,'02	51 H. Cephei s.p.	35.75	2.92	— .12	2.80	
		Mar. 21,'03	λ Urs. min. s.p.	22.35	3.11	— .08	3.03	
		Mar. 21,'03	30 H. Camel.	22.29	3.05	+ .10	3.15	
		Mar. 21,'03	Polaris s.p.	22.80	3.56	— .08	3.48	
	W.R.	Apr. 29,'02	Polaris s.p.	35.87	3.04	— .07	2.97	3.45
		Apr. 29,'02	Gr. 750 s.p.	35.87	3.04	— .15	2.89	
		June 8,'02	Polaris s.p.	37.38	4.55	— .07	4.48	
	E.D.	May 8,'02	Gr. 750 s.p.	38.12	5.29	+ .15	5.44	4.41
		May 8,'02	ε Urs. min.	37.08	4.25	— .10	4.15	
		May 13,'02	Polaris s.p.	35.78	2.95	+ .08	3.03	
		Apr. 27,'03	Gr. 750 s.p.	23.82	4.58	+ .15	4.73	
		Apr. 27,'03	51 H. Cephei s.p.	23.81	4.57	+ .11	4.68	
	E.R.	May 25,'02	Polaris s.p.	37.78	4.95	+ .08	5.03	4.92
		June 26,'02	Gr. 750 s.p.	37.27	4.44	+ .17	4.61	
		June 26,'02	51 H. Cephei s.p.	37.81	4.98	+ .13	5.11	
Below Pole.	W.D.	Oct. 28,'02	Polaris	35.14	2.31	— .08	2.23	3.37
		Oct. 28,'02	Gr. 750	37.57	4.74	— .16	4.58	
		Oct. 30,'02	Polaris	35.61	2.78	— .08	2.70	
		Oct. 30,'02	Gr. 750	36.32	3.49	— .16	3.33	
		Oct. 31,'02	Polaris	36.93	4.10	— .08	4.02	
	W.R.	Jan. 22,'02	Gr. 750	36.14	3.61	— .15	3.46	3.57
		Jan. 22,'02	δ Urs. min. s.p.	36.13	3.30	+ .02	3.32	
		Dec. 18,'02	Polaris	36.26	3.43	— .08	3.35	
		Dec. 18,'02	Gr. 750	36.71	3.88	— .15	3.73	
		Jan. 26,'03	Gr. 750	23.39	4.15	— .15	4.00	
	E.D.	Nov. 21,'02	30 H. Camel. s.p.	37.22	4.39	— .10	4.29	3.94
		Nov. 21,'02	Polaris	37.00	4.17	+ .07	4.24	
		Nov. 24,'02	Polaris	35.73	2.90	+ .07	2.97	
		Nov. 24,'02	Gr. 750	36.95	4.12	+ .14	4.26	
	E.R.	Nov. 19,'02	Polaris	36.15	3.32	+ .09	3.41	3.41
								3.86

TABLE II.—DECLINATIONS FOR 1900.0 FROM COMPARISON WITH ZERO STARS.

URS. MIN. 33 HS., 7.5 MAG., R.A. $15^h\ 53^m\ 47^s$.

		Date.	Zero Star.		Year of Obs. Jan. 0.0	1900.0.	Diff. Flexure	δ—1900.0.	
					83° 14′	83° 14′		83° 14′	Mean.
Above Pole.	W.D.	June 13,'02	Gr. 750	s.p.	38″.01	59″.01	−.26	58″.75	57″.94
		June 13,'02	51 H. Cephei	s.p.	35.89	56.89	−.21	56.68	
		June 14,'02	Gr. 750	s.p.	37.66	58.66	−.26	58.40	
	W.R.	Apr. 29,'02	Polaris	s.p.	36.74	57.74	−.15	57.59	58.08
		Apr. 29,'02	Gr. 750	s.p.	36.74	57.74	−.23	57.51	
		June 8,'02	Polaris	s.p.	38.29	59.29	−.15	59.14	
	E.D.	May 8,'02	Gr. 750	s.p.	37.02	58.02	+.23	58.25	57.94
		May 8,'02	ε Urs. min.	s.p.	35.98	56.98	−.02	56.96	
		May 13,'02	Polaris	s.p.	35.98	56.98	+.16	57.14	
		Apr. 9,'03	76 Draconis	s.p.	26.40	57.92	+.30	58.22	
		Apr. 9,'03	1 H. Draconis		26.77	58.29	−.02	58.27	
		Apr. 9,'03	30 H. Camel.		26.80	58.32	00	58.32	
		Apr. 9,'03	Gr. 750	s.p.	26.70	58.22	+.23	58.45	
	E.R.	May 22,'02	δ Urs. min.	s.p.	37.20	58.20	+.07	58.27	58.37
		May 25,'02	Polaris	s.p.	38.32	59.32	+.18	59.50	
		June 26,'02	Gr. 750	s.p.	37.29	58.29	+.26	58.55	
		June 26,'02	51 H. Cephei	s.p.	37.83	58.83	+.22	59.05	
		Apr. 27,'03	ε Urs. min.		26.14	57.66	−.02	57.64	
		Apr. 27,'03	δ Urs. min.		25.60	57.12	+.07	57.19	
Below Pole.	W.D.	Oct. 28,'02	Polaris		35.81	56.81	−.19	56.62	58.24
		Oct. 28,'02	Gr. 750		38.24	59.24	−.27	58.97	
		Oct. 30,'02	Polaris		37.57	58.57	−.19	58.38	
		Oct. 30,'02	Gr. 750		38.28	59.28	−.27	59.01	
	W.R.								
	E.D.	Nov. 24,'02	Polaris		35.41	56.41	+.17	56.58	57.31
		Nov. 24,'02	Gr. 750		36.63	57.63	+.24	57.87	
		Feb. 5,'03	Polaris		24.71	56.23	+.17	56.40	
		Feb. 5.03	Gr. 750		25.80	57.32	+.24	57.56	
		Feb. 13,'03	Gr. 750		26.16	57.68	+.24	57.92	
		Feb. 13,'03	δ Urs. min.	s.p.	25.90	57.42	+.08	57.50	
	E.R.								
									57.98

TABLE II.—DECLINATIONS FOR 1900.0 FROM COMPARISON WITH ZERO STARS.
CEPHEI 3 HS., 7.0 MAG., R.A. 20h 13m 59s.

		Date.	Zero Star.	Year of Obs. Jan. 0.0.	1900.0.	Diff. Flexure.	δ—1900.0.	Mean.
				84°22′	84 22′		84 22′	
				″	″		″	″
Above Pole	W.D.	June 5, '02	δ Urs. min.	59.19	37.15	— .05	37.10	38.00
		June 27, '02	1 H. Draconis s.p.	61.28	39.24	— .33	38.91	
	W.R.	Oct. 18, '02	1 H. Draconis s.p.	60.15	38.11	— .29	37.82	38.38
		Oct. 21, '02	30 H. Camel. s.p.	60.35	38.31	— .26	38.05	
		Oct. 21, '02	Polaris	61.22	39.18	— .08	39.10	
		Oct. 24, '02	1 H. Draconis s.p.	61.11	39.07	— .29	38.78	
		Oct. 24, '02	Polaris	60.26	38.22	— .08	38.14	
	E.D.	June 17, '02	δ Urs. min.	59.72	37.68	+ .04	37.72	38.32
		June 17, '02	51 H. Cephei s.p.	60.52	38.48	+ .17	38.65	
		June 17, '02	1 H. Draconis s.p.	59.92	37.88	+ .29	38.17	
		Sept. 15, '02	1 H. Draconis s.p.	60.48	38.44	+ .29	38.73	
	E.R.	June 26, '02	Gr. 750 s.p.	60.76	38.72	+ .24	38.96	39.21
		June 26, '02	51 H. Cephei s.p.	61.30	39.26	+ .20	39.46	
Below Pole.	W.D.	Feb. 22, '02	λ Urs. min. s.p.	60.39	38.35	— .11	38.24	38.53
		Mar. 29, '02	λ Urs. min. s.p.	60.66	38.62	— .11	38.51	
		Mar. 29, '02	51 H. Cephei	61.09	39.05	— .20	38.85	
	W.R.	Feb. 15, '02	Gr. 750	59.90	37.86	— .22	37.64	37.64
		Feb. 15, '02	51 H. Cephei	59.86	37.82	— .18	37.64	
		Apr. 10, '02	76 Draconis s.p.	59.62	37.58	+ .05	37.63	
	E.D.	Mar. 4, '02	δ Urs. min. s.p.	60.14	38.10	+ .05	38.15	37.93
		Mar. 5, '02	51 H. Cephei	59.93	37.89	+ .17	38.06	
		Mar. 5, '02	δ Urs. min. s.p.	59.58	37.54	+ .05	37.59	
	E.R.	Mar. 19, '02	λ Urs. min. s.p.	58.77	36.73	+ .11	36.84	37.83
		Mar. 19, '02	51 H. Cephei	61.02	38.98	+ .19	39.17	
		Mar. 8, '03	1 H. Draconis	70.22	37.18	+ .31	37.49	
								38.23

TABLE II.—DECLINATIONS FOR 1900.0 FROM COMPARISON WITH ZERO STARS.
CEPHEI GR. 3548, 7.3 MAG., R.A. 21^h 19^m 35^s.

		Date.	Zero Star.	Year of Obs. Jan. 0 0.	1900.0.	Diff. Flexure.	δ—1900.0.	
				86°37′	86°37′		86°37′	
				″	″		″	Mean. ″
Above Pole.	W.D.	Sept. 22,'02	λ Urs. min.	55.35	24.65	—.05	24.60	24.01
		Oct. 8,'02	λ Urs. min.	54.35	23.65	—.05	23.60	
		Oct. 8,'02	Polaris	54.58	23.88	—.05	23.83	
	W.R.	Oct. 10,'01	76 Draconis	39.34	23.99	+.08	24.07	23.68
		Sept. 26,'02	λ Urs. min.	54.04	23.34	—.05	23.29	
	E.D.	Oct. 23,'01	30 H. Camel. s.p.	39.36	24.01	+.21	24.22	24.19
		Oct. 28,'01	76 Draconis	40.18	24.83	—.08	24.75	
		Nov. 21,'02	30 H. Camel. s.p.	54.36	23.66	+.21	23.87	
		Nov. 21,'02	Polaris	54.58	23.88	+.04	23.92	
	E.R.	Oct. 30,'01	76 Draconis	38.90	23.55	—.09	23.46	24.81
		June 26,'02	Gr. 750 s.p.	55.75	25.05	+.19	25.24	
		June 26,'02	51 H. Cephei s.p.	56.29	25.59	+.15	25.74	
Below Pole.	W.D.	Mar. 29,'02	51 H. Cephei	56.49	25.79	—.15	25.64	24.90
		Mar. 29,'02	λ Urs. min. s.p.	56.06	25.36	—.06	25.30	
		Apr. 11,'02	76 Draconis s.p.	54.17	23.47	+.11	23.58	
		Apr. 11,'02	Polaris s.p.	55.83	25.13	—.06	25.07	
	W.R.	Apr. 10,'02	76 Draconis s.p.	54.84	24.14	+.10	24.24	23.17
		Apr. 15,'02	30 H. Camel.	53.01	22.31	—.21	22.10	
	E.D.	Mar. 4,'02	δ Urs. min. s.p.	55.92	25.22	00	25.22	24.76
		Mar. 5,'02	δ Urs. min. s.p.	54.96	24.26	00	24.26	
		Mar. 5,'02	51 H. Cephei	55.31	24.61	+.12	24.73	
		Feb. 13,'03	Gr. 750	70.88	24.85	+.16	25.01	
		Feb. 13,'03	δ Urs. min. s.p.	70.62	24.59	00	24.59	
	E.R.	Mar. 19,'02	51 H. Cephei	56.44	25.74	+.14	25.88	24.78
		Mar. 19,'02	λ Urs. min. s.p.	54.19	23.49	+.06	23.55	
		Feb. 24,'03	δ Urs. min. s.p.	71.09	25.06	00	25.06	
		Feb. 24,'03	λ Urs. min. s.p.	70.19	24.16	+.06	24.22	
		Feb. 24,'03	30 H. Camel.	70.39	24.36	+.23	24.59	
		Feb. 24,'03	Polaris s.p.	71.38	25.35	+.05	25.40	
								24.28

TABLE II.—DECLINATIONS FOR 1900.0 FROM COMPARISON WITH ZERO STARS.
32 H. CEPHEI, 5.3 MAG., R.A. 22ʰ 21ᵐ 18ˢ.

		Date.	Zero Star.	Year of Obs. Jan. 0.0.	1900.0.	Diff. Flexure.	δ—1900.0.	Mean.
				85 36′	85 36′		85 36′	
Above Pole.	W.D.	Sept. 22,'02	λ Urs. min.	52″.90	16″.37	− .07	16″.30	16″.54
		Oct. 1,'02	1 H. Draconis s.p.	53.61	17.08	− .30	16.78	
	W.R.	Oct. 10,'01	76 Draconis	35.16	16.89	+ .06	16.95	17.28
		Oct. 24,'02	1 H. Draconis s.p.	54.57	18.04	− .27	17.77	
		Oct. 24,'02	Polaris	53.72	17.19	− .06	17.13	
	E.D.	Oct. 28,'01	76 Draconis	36.26	17.99	− .07	17.92	17.04
		June 26,'02	λ Urs. min.	52.29	15.76	+ .06	15.82	
		Sept. 15,'02	1 H. Draconis s.p.	53.63	17.10	+ .27	17.37	
	E.R.	Oct. 30,'01	76 Draconis	35.48	17.21	− .07	17.14	18.10
		June 26,'02	Gr. 750 s.p.	54.65	18.12	+ .21	18.33	
		June 26,'02	51 H. Cephei s.p.	55.19	18.66	+ .17	18.83	
Below Pole.	W.D.	Mar. 29,'02	51 H. Cephei	54.69	18.16	− .17	17.99	17.91
		Mar. 29,'02	λ Urs. min. s.p.	54.26	17.73	− .08	17.65	
		Apr. 11,'02	76 Draconis s.p.	53.31	16.78	+ .09	16.87	
		Apr. 11,'02	Polaris s.p.	54.97	18.44	− .08	18.36	
		Apr. 28,'02	Polaris s.p.	55.28	18.75	− .08	18.67	
	W.R.	Apr. 10,'02	76 Draconis s.p.	53.88	17.35	+ .08	17.43	17.30
		Apr. 24,'02	1 H. Draconis	53.94	17.41	− .25	17.16	
	E.D.	Mar. 24,'02	λ Urs. min. s.p.	53.71	17.18	+ .07	17.25	17.22
		Mar. 24,'02	51 H. Cephei	53.33	16.80	+ .14	16.94	
		Feb. 13,'03	Gr. 750	72.15	17.36	+ .19	17.55	
		Feb. 13,'03	δ Urs. min. s.p.	71.89	17.10	+ .03	17.13	
	E.R.	Mar. 19,'02	51 H. Cephei	54.68	18.15	+ .16	18.31	17.14
		Mar. 19,'02	λ Urs. min. s.p.	52.43	15.90	+ .08	15.98	
		Mar. 21,'02	1 H. Draconis	52.80	16.27	+ .28	16.55	
		Feb. 21,'03	43 H. Cephei s.p.	72.17	17.38	.00	17.38	
		Feb. 21,'03	λ Urs. min. s.p.	72.21	17.42	+ .08	17.50	
								17.32

TABLE II.—DECLINATIONS FOR 1900.0 FROM COMPARISON WITH ZERO STARS.
36 H. CEPHEI, 5.7 MAG., R.A. 22h 55m 13s.

		Date.	Zero Star.	Year of Obs. Jan. 0.0.	1900.0.	Diff. Flexure.	δ—1900.0.	
				83°48′	83°48′		83°48′	Mean.
				″	″		″	
Above Pole.	W.D.	Oct. 4, '01	30 H. Camel. s.p.	59.23	39.96	— .30	39.66	39.73
		Sept.22, '02	λ Urs. min.	78.46	39.91	— .11	39.80	
	W.R.	Oct. 5, '01	30 H. Camel. s.p.	59.35	40.08	— .27	39.81	40.25
		Oct. 10, '01	76 Draconis	58.94	39.67	+ .03	39.70	
		Dec. 6, '01	43 H. Cephei	59.06	39.79	— .03	39.76	
		Dec. 6, '01	Polaris	60.29	41.02	— .09	40.93	
		Oct. 21, '02	30 H. Camel. s.p.	78.61	40.06	— .27	39.79	
		Oct. 21, '02	Polaris	79.48	40.93	— .09	40.84	
		Oct. 24, '02	1 H. Draconis s.p.	79.77	41.22	— .30	40.92	
		Oct. 24, '02	Polaris	78.92	40.37	— .09	40.28	
	E.D.	Oct. 23, '01	30 H. Camel. s.p.	59.38	40.11	+ .27	40.38	39.80
		Oct. 25, '01	30 H. Camel. s.p.	58.22	38.95	+ .27	39.22	
	E.R.	Oct. 22, '01	43 H. Cephei	61.23	41.96	+ .04	42.00	41.34
		Nov.26, '01	43 H. Cephei	60.77	41.50	+ .04	41.54	
		Nov.30, '01	30 H. Camel. s.p.	59.44	40.17	+ .31	40.48	
Below Pole.	W.D.	Mar. 29, '02	51 H. Cephei	81.16	42.61	— .21	42.40	40.70
		Mar. 29, '02	λ Urs. min. s.p.	80.73	42.18	— .12	42.06	
		Apr.28, '02	Polaris s.p.	79.22	40.67	— .12	40.55	
		May 2, '02	30 H. Camel.	76.60	38.05	— .27	37.78	
	W.R.	Apr.10, '02	76 Draconis s.p.	79.01	40.46	+ .04	40.50	39.40
		Apr.15, '02	30 H. Camel.	77.11	38.56	— .27	38.29	
	E.D.	May 16, '02	43 H. Cephei s.p.	78.68	40.13	+ .04	40.17	40.12
		May 16, '02	Polaris s.p.	78.53	39.98	+ .10	40.08	
	E.R.	Feb. 13, '03	51 H. Cephei	97.64	39.82	+ .21	40.03	39.62
		Feb. 24, '03	δ Urs. min. s.p.	97.51	39.69	+ .07	39.76	
		Feb. 24, '03	λ Urs. min. s.p.	96.61	38.79	+ .13	38.92	
		Feb. 24, '03	30 H. Camel.	96.81	38.99	+ .30	39.29	
		Feb. 24, '03	Polaris s.p.	97.80	39.98	+ .12	40.10	
								40.12

TABLE II.—DECLINATIONS FOR 1900.0 FROM COMPARISON WITH ZERO STARS.
39 H. CEPHEI, 5.9 MAG., R.A. 23h 27m 49s.

		Date.	Zero Star.		Year of Obs. Jan. 0.0.	1900.0.	Diff. Flexure.	δ—1900.0.	
					86° 45′	86° 45′		86° 45′	
Above Pole.	W.D.	Oct. 4, '01	30 H. Camel.	s.p.	41″.86	21″.99	— .24	21″.75	Mean. 21.44
		Dec. 11, '01	43 H. Cephei		41.37	21.50	+ .02	21.52	
		Sept. 22, '02	λ Urs. min.		60.84	21.10	— .05	21.05	
	W.R.	Oct. 5, '01	30 H. Camel.	s.p.	40.87	21.00	— .22	20.78	20.83
		Oct. 7, '01	30 H. Camel.	s.p.	40.99	21.12	— .22	20.90	
		Dec. 6, '01	43 H. Cephei		40.08	20.21	+ .02	20.23	
		Dec. 6, '01	Polaris		41.31	21.44	— .04	21.40	
	E.D.	Oct. 23, '01	30 H. Camel.	s.p.	41.11	21.24	+ .21	21.45	20.54
		Oct. 25, '01	30 H. Camel.	s.p.	39.30	19.43	+ .21	19.64	
	E.R.	Oct. 22, '01	43 H. Cephei		42.04	22.17	— .03	22.14	21.69
		Nov. 9, '01	43 H. Cephei		42.90	23.03	— .03	23.00	
		Nov. 30, '01	30 H. Camel.	s.p.	41.00	21.13	+ .24	21.37	
		Nov. 21, '02	Polaris		61.28	21.54	+ .04	21.58	
		Nov. 21, '02	Gr. 750		60.14	20.40	— .04	20.36	
Below Pole.	W.D.	Apr. 11, '02	76 Draconis	s.p.	59.62	19.88	+ .12	20.00	20.58
		Apr. 11, '02	Polaris	s.p.	61.28	21.54	— .05	21.49	
		Apr. 28, '02	Polaris	s.p.	61.02	21.28	— .05	21.23	
		May 2, '02	30 H. Camel.		59.54	19.80	— .20	19.60	
	W.R.	Apr. 10, '02	76 Draconis	s.p.	61.19	21.45	+ .11	21.56	21.50
		Apr. 24, '02	1 H. Draconis		61.40	21.66	— .22	21.44	
	E.D.	May 16, '02	43 H. Cephei	s.p.	60.53	20.79	— .02	20.77	20.67
		May 16, '02	Polaris	s.p.	60.38	20.64	+ .04	20.68	
		May 24, '02	Polaris	s.p.	60.26	20.52	+ .04	20.56	
	E.R.	May 9, '02	Polaris	s.p.	60.68	20.94	+ .05	20.99	20.65
		Feb. 6, '03	76 Draconis	s.p.	79.71	20.09	— .11	19.98	
		Feb. 6, '03	1 H. Draconis		80.78	21.16	+ .26	21.42	
		Feb. 24, '03	δ Urs. min.	s.p.	80.41	20.79	00	20.79	
		Feb. 24, '03	λ Urs. min.	s.p.	79.51	19.89	+ .06	19.95	
		Feb. 24, '03	30 H. Camel.		79.71	20.09	+ .23	20.32	
		Feb. 24, '03	Polaris	s.p.	80.70	21.08	+ .05	21.13	
									20.99

TABLE II. — DECLINATION FOR 1900.0 FROM COMPARISON WITH ZERO STARS.
CEPHEI 125 HS., 6.3 MAG., R.A. 23^h 51^m 46^s.

		Date.	Zero Star.	Year of Obs. Jan. o.o.	1900.o.	Diff. Flexure.	δ—1900.o.	
				82°38′	82°38′		82°38′	Mean.
Above Pole.	W.D.	Oct. 1,'02	1 H. Draconis s.p.	43″.65	3″.54	— .37	3″.17	4″.32
		Oct. 6,'02	76 Draconis	44.40	4.29	+ .01	4.30	
		Oct. 6,'02	30 H. Camel. s.p.	45.13	5.02	— .33	4.69	
		Oct. 7,'02	λ Urs. min.	45.01	4.90	— .15	4.75	
		Oct. 7,'02	Polaris	44.93	4.82	— .14	4.68	
	W.R.	Oct. 5,'01	30 H. Camel. s.p.	23.02	2.97	— .29	2.68	3.42
		Dec. 5,'01	43 H. Cephei	23.20	3.15	— .05	3.10	
		Dec. 6,'01	43 H. Cephei	23.46	3.41	— .05	3.36	
		Dec. 6,'01	Polaris	24.69	4.64	— .11	4.53	
	E.D.	Oct. 28,'01	76 Draconis	24.17	4.12	— .01	4.11	3.70
		Nov. 18,'01	43 H. Cephei	25.01	4.96	+ .06	5.02	
		Nov. 21,'02	30 H. Camel. s.p.	42.64	2.53	+ .29	2.82	
		Nov. 21,'02	Polaris	42.86	2.75	+ .12	2.87	
	E.R.	Oct. 22,'01	43 H. Cephei	24.80	4.75	+ .06	4.81	3.97
		Oct. 29,'01	76 Draconis	22.73	2.68	— .01	2.67	
		Nov. 19,'02	Polaris	44.41	4.30	+ .13	4.43	
Below Pole.	W.D.	Apr. 11,'02	76 Draconis s.p.	44.80	4.69	+ .02	4.71	5.15
		Apr. 11,'02	Polaris s.p.	46.46	6.35	— .15	6.20	
		Apr. 28,'02	Polaris s.p.	45.29	5.18	— .15	5.03	
		Mar. 21,'03	λ Urs. min. s.p.	65.48	5.32	— .15	5.17	
		Mar. 21,'03	30 H. Camel.	65.54	5.38	— .33	5.05	
		Mar. 21,'03	Polaris s.p.	65.03	4.87	— .15	4.72	
	W.R.	Apr. 10,'02	76 Draconis s.p.	43.88	3.77	+ .01	3.78	2.78
		Apr. 15,'02	30 H. Camel.	42.66	2.55	— .30	2.25	
		Mar. 25,'03	λ Urs. min. s.p.	62.81	2.65	— .14	2.51	
		Mar. 25,'03	30 H. Camel.	62.58	2.42	— .30	2.12	
		Mar. 25,'03	Polaris s.p.	63.53	3.37	— .14	3.23	
	E.D.	May 9,'02	Polaris s.p.	43.14	3.03	+ .13	3.16	3.72
		May 9,'02	43 H. Cephei s.p.	44.60	4.49	+ .07	4.56	
		May 16,'02	43 H. Cephei s.p.	44.01	3.90	+ .07	3.97	
		May 16,'02	Polaris s.p.	43.86	3.75	+ .13	3.88	
		May 24,'02	Polaris s.p.	43.02	2.91	+ .13	3.04	
	E.R.	Feb. 13,'03	51 H. Cephei	64.01	3.85	+ .24	4.09	3.96
		Mar. 2,'03	δ Urs. min. s.p.	63.58	3.42	+ .10	3.52	
		Mar. 2,'03	51 H. Cephei	64.69	4.53	+ .25	4.78	
		Mar. 2,'03	1 H. Draconis	63.51	3.35	+ .35	3.70	
		Mar. 2,'03	Polaris s.p.	63.74	3.58	+ .15	3.73	
								3.88

TABLE III. — OBSERVED DECLINATIONS FOR 1900.0 COMPARED WITH CATALOGUE PLACES.

Name.	Right Ascension.			Declinations.						
				Observed.				Newcomb's Fundamental Catalogue.	Berliner Jarbuch for 1900.	B. J. for 1906 with Corrections, Reduced to 1900.0.
				Absolute.			Fr. Comparison with Zero Stars.			
	h	m	s	°	′	″	″	″	″	
43 H. Cephei	0	55	1	85	43	14.55		14.74	14.82	14.52
Polaris	1	22	33	88	46	26.64		26.61	26.63	26.50
Cephei, Br. 256	2	1	25	83	5	30.44	30.22			
Cephei 147 Hs.	3	8	35	84	33	[26.87]	26.59			
Cephei 149 Hs.	3	33	55	86	19	[56.87]	56.86			
Gr. 750	4	5	5	85	17	28.72			28.18	28.81
Cephei 157 Hs.	4	56	18	85	49	46.34	46.48			
Cephei 158 Hs.	5	29	55	85	8	49.92	50.19	49.60		
51 H. Cephei	6	53	45	87	12	20.57		20.53	20.15	20.05
Cephei 109 Hs.	7	53	2	84	20	49.76	49.57			
Urs. min. 4B.	7	58	3	88	55	59.29	59.11	59.36		
Ceph. 121 Hs.	8	54	32	84	34	58.33	58.40			
1 H. Draconis	9	22	51	81	46	6.98		6.91	6.99	6.72
30 H. Camel.	10	18	55	83	4	2.80		2.78	3.32	3.28
Camel., s 664	11	2	30	86	10	[57.78]	58.00			
Urs. min. 3 Hs.	12	14	23	88	15	14.74	14.85	15.20		
32 H. Camel. pr.	12	48	16	83	57	41.03	41.28			
32 H. Camel. seq.	12	48	23	83	57	23.31	23.59	23.39		
Ceph. 135 Hs.	13	45	10	83	15	14.99	15.14			
Urs. min. 57B	15	9	21	87	37	3.49	3.86	4.04		
Urs. min. 33 Hs.	15	53	47	83	14	[57.62]	57.98			
ε *Urs. min.*	16	56	12	82	12	[7.63]		7.68	7.66	7.85
δ *Urs. min.*	18	4	33	86	36	48.08		47.71	47.52	48.13
λ *Urs. min.*	19	22	30	88	59	15.98		15.81	15.43	15.94
Cephei 3 Hs.	20	13	59	84	22	38.10	38.23			
76 Draconis	20	49	51	82	9	40.36		40.01	39.66	40.23
Ceph., Gr. 3548	21	19	35	86	37	24.64	24.28	24.85		
32 H. Cephei	22	21	18	85	36	17.29	17.32			
36 H. Cephei	22	55	13	83	48	40.04	40.12			
39 H. Cephei	23	27	49	86	45	21.12	20.99	21.14		
Ceph. 125 Hs.	23	51	46	82	38	4.05	3.88			

PROCEEDINGS

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THE CAMBRIAN FAUNA OF INDIA.

BY CHARLES D. WALCOTT.

THROUGH the courtesy of the Director of the Geological Survey of India, I have had the opportunity of studying the collections of Cambrian fossils from the Cambrian rocks of the Salt Range. The fauna was first described by Dr. William Waagen[1] and later by Dr. K. Redlich.[2] In order to have a stratigraphic section to which the subfaunas may be referred, the following is made up from Dr. Fritz Noetling's[3] sections and Dr. Redlich's[4] statements of the occurrence of the fossils. Dr. Noetling's detailed sections[5] give the stratigraphic succession and character of the Cambrian shales and sandstones, and prove that the sediments of the eastern section of the Salt Range were deposited mainly near shore. The fossils show that they were subjected to the vicissitudes of life on a shifting, sandy and muddy bottom.

Age of the Contained Fauna. — The first reference of the brachiopods of the lower strata of the Salt Range was to the Silurian.[6] Subsequently they were referred by Dr. Waagen to

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[1] Mem. Geol. Sur. India, Ser. XIII, Vol. I, pp. 748–770, 1885; Vol. IV, pp. 89–108, 1891.

[2] Mem. Geol. Sur. India, New Ser., Vol. I, pp. 1–13, 1899.

[3] Records Geol. Sur. India, Vol. XXVII, 1894, pp. 74–86. Geol. Salt Range, N. Jahr. Mem. Geol. and Pal., 1901, Bd. XIV, p. 416.

[4] *Loc. cit.*, p. 9.

[5] Rec. Geol. Sur. India, Vol. XXVII, 1894, pp. 74–86.

[6] Mr. Wynne, Geol. Salt Range in the Punjab, Mem. Geol. Sur. India, Vol. XIV, p. 86.

Cambrian	Baganwalla group				No fossils found.
	Jutana group		*c.* Upper magnesian limestone. *b.* Middle magnesian limestone. *a.* Lower magnesian limestone. Thickness about 180 feet.	180	*Pseudotheca waageni*, *Ptychoparia richteri*. *Lingulella fuchsi*.
	Kussak group	V	Dark compact shaly thin-bedded and subconcretionary, micaceous but not glauconitic. Thickness 15–18 feet.	15–18	*Redlichia nœtlingi*. *Hyolithes*. *Obolus* (*Lingulella*) *fuschi*, *O.* (*Lingulella*) *wanniecki*, *Acrothele* (*Mobergia*) *granulata*.
		IV	Thin-bedded purple, sandy and micaceous shales. Thickness approximately 15 feet.	15	*Discinolepis granulata*, *Schizopholis rugosa*, *Neobolus warthi*, *Lakhmina linguloides*, *Obolus* (*Lingulella*) *kiurensis*.
		III	Upper Annelid sandstone. A series of hard cream-colored sandstones, flaggy and glauconitic, alternating with soft, dark and shaly layers. Thickness about 40 feet.	40	*Ptchoparia ? warthi*, *P. ? indicus Waagen*, *Hyolithes wynnei*, *Hyolithes kussakensis*, *Wynnia warthi*.
		II	Dark purple shales with green patches. Thickness about 10 feet.	10	*Hyolithes wynnei*, and fragments of undetermined trilobite.
		I	Lower Annelid sandstone. A series of hard cream-colored sandstones, alternating with darker shaly partings or soft sandy beds. Thickness about 50 feet.	50	Annelid trails and fragments of brachiopods and *Hyolithes*.
	Khewra group		Purple sandstones. 200–400 feet thick.	200 to 400	No fossils found.
Pre-Cambrian			Salt marls.		

the Carboniferous fauna.[1] On the discovery of Cambrian trilobites Dr. Waagen referred the fauna to the Cambrian,[2] and tentatively concluded that the Olenus, Paradoxides and Olenellus

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[1] *Loc. cit.*, 1885.

[2] *Loc. cit.*, 1891, p. 94.

faunas might be represented.[1] Later (1899) Dr. K. Redlich described the collections made by Messrs. Middlemiss and Noetling, and concluded that the Cambrian fauna of the Salt range cannot be referred to a later horizon than the Paradoxides zone[2]. My review of the type material received from Dr. Holland and a small collection made for me by Dr. Fritz Noetling lead me to agree with Dr. Redlich and also to add that there is no evidence that the fauna is much older than the Paradoxides or Middle Cambrian fauna.

The supposed heads of *Olenellus* mentioned by Dr. Waagen are very properly referred by Dr. Redlich to a new genus named by him *Hoeferia* which name being preoccupied was replaced by *Redlichia* by Cossman.[3] This genus differs from *Olenellus* "by the presence of a well-developed facial suture and by the distinct separation of the eyes from the glabella."[4] Another difference is the absence of the characteristic surface sculpture of *Olenellus*.[5] My present impression is that *Redlichia* is a direct descendant of *Olenellus* and that it lived in late Lower Cambrian or Middle Cambrian time.

Dr. Redlich calls attention to the resemblance between *Redlichia*, and *Protolenus* Matthew, but he does not note the resemblance to *Zacanthoides* Walcott.[6] Both *Protolenus* and *Zacanthoides* are Middle Cambrian genera. The former occurs just below the Paradoxides fauna on Handford Brook, New Brunswick, and the Olenellus fauna is found 460 to 480 feet

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[1] *Loc. cit.*, p. 106.

[2] Mem. Geol. Sur. India, N. Ser., Vol. 1, 1899, p. 11.

[3] Revue Cretiqué Paléozoologie, Sixième Ann., 1902, p. 52.

[4] *Loc. cit.*, p. 2.

[5] Dr. Redlich states that Walcott mentions the presence of facial suture in *Olenellus* and quotes from page 175 of Bulletin 30, U. S. Geol. Survey, 1886. In 1891 I wrote of the supposed suture in *Olenellus*: "The discovery of more perfect specimens of *O.* (*M.*) *asaphoides* shows that what I had identified as the facial suture is a raised line in the coat of the interior of the shell that fills a depressed line occupying the position of the suture. I have since found this line in many specimens but in none is there a true suture cutting through the shell, as in *Paradoxides* and most other genera of trilobites." (Tenth Ann. Rep. U. S. Geol. Sur., 1891, pp. 633, 634).

[6] As shown on plate XXV, figures 2, 3, 4 and 6, Bulletin 30, U. S. Geol. Surv., 1886.

beneath in the same section.[1] In western Utah, in the House range, the Middle Cambrian contains over 400 feet of strata and is characterized by four subfaunas of which Zacanthoides is the oldest.[2] To the westward in Nevada, the Olenellus fauna ranges through 5,000 feet of beds, and the Upper Cambrian fauna is found 1,500 feet above the Middle Cambrian fauna in the Highland range.[3]

By reference to the table showing the Cambrian formations of the Salt Range and contained fossils (*ante*, p. 252) it will be noted that there are only 115 feet of fossiliferous strata beneath the beds containing *Redlichia nœtlingi* and the basal sandstone. In the absence of any fossils clearly indicating the Olenellus fauna I think it is unwise at present to assume any other age for the fossiliferous Cambrian beds than Middle Cambrian. The brachiopods of division IV, Neobolus beds, of the Khussak group, indicate a stage of evolution in advance of any brachiopod we know in the Olenellus fauna. *Lakhmina linguloides* with its interior platforms and perforate ventral valve and *Neobolus warthi* with its central platform in the ventral valve indicate Ordovician rather than Lower Cambrian development.

Notes on the Fossils.—The annelid trails are of the usual forms occurring on the surface and penetrating the sandy layers. Dr. Redlich illustrates a form of *Cylindrites*, and states that many worm-trails remain alike from the Cambrian to the present day.[4]

Brachiopoda: Obolus (*Lingulella*) *wanniecki* Redlich and *O.* (*L.*) *kiurensis* Waagen, are essentially Middle Cambrian forms and *O.* (*L.*) *fuchsi* suggests the Upper Cambrian, *Lingulepis*-like shells. *Acrothele* (*Mobergia*) *granulata* Redlich is not unlike *Acrothele subsidua* White, which is abundant in the Middle Cambrian of Utah. The brachiopods, *Discinolepis granulata* Waagen, *Schizopholus rugosa* Waagen, *Neobolus*

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[1] Lower Cambrian terrane in the Atlantic Province, Proc. Washington Acad. Sci., Vol. I, pp. 320-322.

[2] This section was examined in 1903. I expect to study it more in detail this season (1905) as it is the most complete section of the Middle Cambrian zone known to me in America.

[3] Bull. 30, U. S. Geol. Surv., pp. 33-35.

[4] Loc. cit., p. 8, pl. I, figs. 19 and 20.

warthi Waagen and *Lakhmina linguloides* Waagen all indicate a stage of development more advanced than that of the brachiopods of the Cambrian faunas in other parts of the world. *Wynnia warthi* Waagen is the only articulate brachiopod in the collection; it is related to both *Nisusia* and *Billingsella* of the Lower and Middle Cambrian faunas.

Pteropoda: The fragments representing *Hyolithes kussakensis* Waagen is undistinguishable from young shells of *Hyolithes primordialis* Hall and *H. americanus* Billings. A similar, if not identical, species occurs with *Redlichia* (*Hœferia*) *nœtlingi* in Division V. *Hyolithes wynnei* Waagen is clearly distinguished by the median furrow on the ventral side from other species of the genus. It occurs in Divisions II and III. *Pseudotheca waageni* Redlich is one of the doubtful forms which has little stratigraphic value. Its relations appear to be with *Stenotheca*.

Trilobita: Reference has already been made to *Redlichia nœtlingi* Redlich when speaking of the stratigraphic position of the genus. The genus occurs in China in the basal fossiliferous beds, but it is not far below the characteristic Middle Cambrian fauna. As has been stated, I regard the genus as of late Lower Cambrian or early Middle Cambrian age. *Ptychoparia richteri* Redlich from the Magnesian limestone series is a form that might well occur at any horizon of the Cambrian although it is more of a Middle Cambrian type. The same may be said of *Ptychoparia warthi* from Division III. A fragment of the central portions of the head of a trilobite from Division III, was named *Olenus indicus* by Waagen. The pustulose surface and strong, rounded glabella indicate a species more nearly related to *Conocoryphe trilineatus* Emmons of the Lower Cambrian fauna than *Olenus* of the Upper Cambrian fauna. The fragment is hardly sufficient to base a generic or specific determination upon. The stratigraphic horizon of this species is in doubt. It probably came from Division IV, as the associated *Hyolithes kussakensis* is abundant in the superjacent shales of Division V.

As stated by Dr. Redlich, the composition of the fauna is very simple. In Division IV there is an unusually remarkable development of brachiopods, but only 5 species are present. In Division V the large trilobite, *Redlichia nœtlingi*, may indicate the horizon of the lower beds of the eastern China section or the Middle Cambrian, as the genus ranges up to the summit of the Middle Cambrian. Only 4 other species of fossils occur at this horizon in India. My impression is that systematic search will give a larger fauna from the Salt Range, and that when this is obtained some revision of our present views of the stratigraphic succession and age of the various parts of the known fauna may be necessary.

PROCEEDINGS

OF THE

WASHINGTON ACADEMY OF SCIENCES

VOL. VII, PP. 257–266. JULY 24, 1905.

ON BASIC SUBSTITUTIONS IN THE ZEOLITES.

By F. W. CLARKE.

DURING the past 7 or 8 years a number of researches upon the constitution of the natural silicates have been carried out in the laboratory of the United States Geological Survey. Some remarkable results have been obtained; and it is now seen that the zeolitic minerals exhibit a high degree of chemical plasticity. Sodium and calcium are easily withdrawn from them, and replaced by other metals or basic radicles; and some of the more striking examples of these reactions are already on record. In Survey Bulletin 207, for instance, a number of ammonium substitution derivatives are described, such as ammonium analcite, ammonium natrolite, and so on. In Bulletin 262, data are given concerning silver and thallium salts of similar character, and the list might be extended almost indefinitely. A large and novel field of investigation is now open, which is not likely to be soon exhausted.

In addition to the compounds just mentioned, a number of interesting sodium, strontium and barium derivatives have been prepared and studied during the past year by Mr. H. C. McNeil. His work will be published in detail, later; the present communication gives only a summary of his results, together with some theoretical discussion. A few of Mr. Steiger's preparations are also cited, for purposes of comparison, and to illustrate the range of the observations.

The mineral analcite has proved to be peculiarly susceptible to transformation, and has yielded derivatives most easily. They may be tabulated as follows:

Analcite	$NaAlSi_2O_6.H_2O$.
Ammonium analcite	$NH_4AlSi_2O_6$.
Silver analcite	$AgAlSi_2O_6.H_2O$.
Thallium analcite	$TlAlSi_2O_6$.
Strontium analcite	$SrAl_2Si_4O_{12}$.
Barium analcite	$BaAl_2Si_4O_{12}$.

The ammonium, silver and thallium compounds, prepared by Mr. Steiger, are all very definite and stable. They were formed by heating analcite with ammonium chloride to 350°, or by fusing analcite with the nitrate of silver or of thallium, and the temperature of the reactions was relatively low. For that reason there was little or no breaking down of the fundamental molecule. The barium and strontium salts, prepared by Mr. McNeil, were obtained by fusing the mineral with barium or strontium chloride, and afterwards leaching the product with water, when the new compounds remained undissolved. The temperature of their formation was unavoidably high, and some decomposition evidently occurred. In fact, in both cases, silica and alumina were found in the leach water in surprising amounts. In the preparation of strontium analcite 36.2 per cent. of the original silica, and 23.36 per cent. of the alumina were thus leached out; and the insoluble residue had the subjoined composition. The composition of the ideal $SrAl_2Si_4O_{12}$ is given in the second column.

	Found.	Calculated.
SiO_2	50.38	53.92
Al_2O_3	26.01	22.88
SrO	23.21	23.20
Cl	trace	——
	99.60	100.00

The sodium of the original analcite had been completely replaced by strontium, but the product obtained was not absolutely pure.

With barium analcite the results were better, as may be seen in Mr. McNeil's analyses of three distinct preparations. In the last column I give the theoretical composition of the salt.

	Found.	Found.	Found.	Calculated.
SiO_2	43.73	45.61	45.22	48.54
Al_2O_3	20.75	20.71	21.09	20.57
BaO	32.95	31.36	33.02	30.89
H_2O	2.02	1.78	.44	——
	99.45	99.46	99.77	100.00

Here again a perfect replacement of sodium has been effected, and a close approximation to the true barium analcite is shown in the analyses.

Stilbite, which is a calcium alumosilicate, has also been carefully studied. Mr. Steiger prepared its ammonium and thallium derivatives, and Mr. McNeil obtained a sodium salt by fusing the mineral with sodium chloride. The analyses are as follows:

	Steiger. Stilbite.	Steiger. NH_4 Salt.	Steiger. Tl Salt.	McNeil. Na Salt.	McNeil. Na Salt.
SiO_2	55.41	60.73	36.75	65.58	64.49
Al_2O_3	16.85	18.31	11.74	20.21	19.91
Fe_2O_3	.18	——	——	——	——
MgO	.05	——	——	——	——
CaO	7.78	1.66	.68	.79	1.02
Na_2O	1.23	.12	.15	12.10	13.11
$(NH_4)_2O$	——	7.83	——	——	——
Tl_2O	——	——	42.94	——	——
H_2O	19.01	10.73	7.77	——	——
Cl	——	1.18	——	1.75	1.68
	100.51	100.56	100.03	100.43	100.21
Less O.	——	.26	——	.40	.38
		100.30		100.03	99.83

If we throw out the water of crystallization as extraneous, the molecular ratios give the following empirical formulæ for the anhydrous compounds. The two sodium preparations are averaged together, and the monoxide bases are united under the general symbol $R_2'O$.

Stilbite (Ca salt)	$R_{317}'Al_{360}Si_{1000}O_{2731}$.
NH_4 salt	$R_{373}'Al_{356}Si_{1000}O_{2705}Cl_{32}$.
Tl salt	$R_{376}'Al_{376}Si_{1000}O_{2751}$.
Na salt	$R_{408}'Al_{367}Si_{1000}O_{2734}Cl_{38}$.

The analyses show clearly the extent of the substitutions effected in stilbite, and the formulæ indicate the persistency of the original type.

Chabazite, like stilbite, is essentially a calcium aluminum trisilicate, and it yields substitution derivatives quite readily. It has, however, a noteworthy tendency to take up extra atoms or groups of atoms, and the analyses consequently show the presence of chlorides or nitrates thus retained. The figures in the following table represent some of these products.

	Steiger. Chabazite.	Steiger. NH_4 Salt.	Steiger. Ag Salt.	Steiger. Tl Salt.	McNeil. Na Salt.
SiO_2	50.78	56.09	34.95	28.92	54.77
Al_2O_3	17.18	19.49	11.89	10.75	20.36
Fe_2O_3	.40	——	——	——	——
MgO	.04	——	——	——	——
CaO	7.84	2.01	——	.65	1.52
Na_2O	1.28	.24	.40	.28	17.42
K_2O	.73	——	——	——	——
$(NH_4)_2O$	——	7.39	——	——	——
Ag_2O	——	——	39.63	——	——
Tl_2O	——	——	——	51.58	——
H_2O	21.85	13.45	6.78	4.15	.28
N_2O_5	——	——	6.64	3.54	——
Cl	——	1.35	——	——	6.92
	100.10	100.02	100.29	99.87	101.27
Less O	——	.30	——	——	1.56
		99.72			99.71

From the molecular ratios the following formulæ for chabazite and its derivatives are deduced.

Chabazite (Ca salt)	$R_{402}'Al_{404}Si_{1000}O_{2807}$.
NH_4 salt	$R_{387}'Al_{408}Si_{1000}O_{2786}Cl_{38}$.
Ag salt	$R_{608}'Al_{402}Si_{1000}O_{2803}(NO_3)_{209}$.
Tl salt	$R_{570}'Al_{436}Si_{1000}O_{2871}(NO_3)_{137}$.
Na salt	$R_{674}'Al_{438}Si_{1000}O_{2892}Cl_{202}$.

The regularity of these ratios is disturbed by the presence of the Cl and NO_3 radicles, whose functions will be considered later. The barium chabazite, prepared by Mr. McNeil, shows even greater irregularities, and uniform products were not obtained. In one experiment the melt of chabazite and barium chloride, upon leaching, yielded two products, one glassy, the other flocculent, which were partially separable mechanically. A second preparation was entirely glassy. The analyses of these products gave the subjoined results: (*A*) Glassy, first preparation; (*B*) flocculent, first preparation; (*C*) second preparation.

	A.	B.	C.
SiO_2	43.63	43.17	39.68
Al_2O_3	17.12	21.24	16.31
BaO	31.58	35.21	40.37
Cl	9.53	.55	5.44
	101.86	100.17	101.80
Less O	2.15	.12	1.23
	99.71	100.05	100.57

The empirical formulæ are as follows:

A. . . . . $Ba_{286}Al_{463}Si_{1000}O_{2793}Cl_{371}$.
B. . . . . $Ba_{327}Al_{582}Si_{1000}O_{3181}Cl_{21}$.
C. . . . . $Ba_{401}Al_{486}Si_{1000}O_{3014}Cl_{232}$.

Although the replacement of monoxide bases by barium is complete, the products are evidently mixtures, and their ratios are not easy to interpret. The fact that *A*, rich in chlorine, and *B*, almost chlorine free, both came from the same melt, indicates a breaking down of the molecules. This suspicion is confirmed by a study of the leach waters. In the washings from *A* and *B*, Mr. McNeil found 15.85 per cent. of the original silica of the chabazite, with 13.10 per cent. of the alumina. The leachings from *C* similarly contained 20.3 of the silica and 11.96 of the alumina. The flocculent compound *B* approximates very roughly in composition to a salt of the type $Ba_3Al_6(SiO_4)_4(Si_3O_8)_2$, but *A* is not reducible to any rational formula. It is probable that a series of reactions took place, in which barium chabazite was first formed and afterwards partly broken down or otherwise modified by the continued action of the molten barium chloride. The solvent effect of the latter salt upon silica and alumina is quite marked, and was studied by Mr. McNeil upon the pure oxides or hydroxides. In four experiments, one gramme of finely divided silica was acted upon by fused barium chloride for 30 minutes. Upon leaching and filtering, the following quantities of silica were found to have been dissolved:

1. 0.0973 gramme, = 9.73 per cent.
2. .0592 " = 5.92 " "
3. .0945 " = 9.45 " "
4. .0771 " = 7.71 " "

When aluminum hydroxide equivalent to one gramme of Al_2O_3 was fused for 30 minutes with 20 grammes of $BaCl_2$, 11.15 per cent. of it went into solution in the washings. Ignited alumina, however, was not attacked. From these experiments it seems probable that when zeolitic derivatives are formed and partly decomposed, the decomposition products pass largely into solution upon leaching. Irregularity in the composition of the residues is therefore to be expected; and in the order which was actually observed in the analyses of barium and strontium analcite.

The presence of Cl and NO_3 in the substituted stilbite and chabazite remains to be interpreted. The simplest explanation of the facts is that adopted by Mr. Steiger in Bulletin 262, where it is assumed that chlorides or nitrates as such are retained or occluded by the residues. When these substances are deducted from the analyses, the remainders agree closely with the theoretical composition of the derived zeolites. But this explanation is not the only one possible. We may imagine that new compounds have been formed, analogous to if not identical with such silicates as sodalite or marialite; and it is worth while to examine the data from this point of view.

The simplest formula assignable to stilbite, regarding all water as crystalline, represents the species as a mixture of the two isomorphous salts

$$Na_2Al_2(Si_3O_8)_2.6H_2O,$$

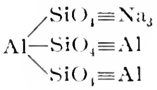
$$CaAl_2(Si_3O_8)_2.6H_2O;$$

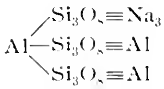
with the calcium compound largely predominating. In chabazite we have a similar commingling of

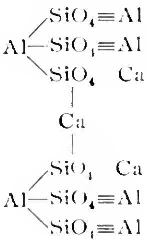
$$(CaNa_2)Al_2(SiO_4)_2.4H_2O,$$

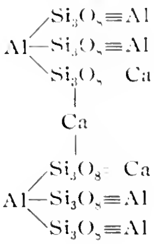
$$(CaNa_2)Al_2(Si_3O_8)_2.8H_2O,$$

the calcium and the trisilicate being most abundant. The true formulæ are probably multiples of these, and the anhydrous salts are perhaps best figured by the following expressions, which represent the salts as isomers of nepheline and albite, with their equivalent calcium compounds:









From formulæ of this character, structures of many types are derivable, and some of them may contain chlorine. The sodium stilbite, prepared by Mr. McNeil, may be represented thus:

the last molecule having been formed by loss of silica from the original trisilicate molecule. This set of symbols corresponds to the percentage composition given below, as contrasted with the average of McNeil's two analyses.

	Calculated.	Found.
SiO_2	64.88	65.03
Al_2O_3	20.05	20.06
CaO	13.72	.91
Na_2O		12.60
Cl	1.74	1.71
	100.39	100.31
Less O	.39	.38
	100.00	99.93

The sodium chabazite agrees well with a mixture of the second and third molecules in the expression given above, in the ratio of 5 : 3; thus:

$$5Al_2Na_3(Si_3O_8)_2Cl;$$
$$3Al_2Na_3(SiO_4)_2Cl;$$

which compares as follows:

	Calculated.	Found.
SiO_2	54.90	54.77
Al_2O_3	20.67	20.36
CaO	18.85	1.52
Na_2O		17.42
Cl	7.10	6.92
H_2O	——	.28
	101.52	101.27
Less O	1.52	1.56
	100.00	99.71

In silver chabazite, which was prepared by the action of silver nitrate upon the mineral, NO_3 appears in place of Cl, and we have

$$3Al_2Ag_3(Si_3O_8)_2NO_3;$$
$$1Al_2Ag_3(SiO_4)_2NO_3;$$

which compares as follows. The *reduced* analysis was computed from Mr. Steiger's analysis by rejecting water, transforming Na_2O into the equivalent amount of Ag_2O, and recalculating to 100 per cent.

	Calculated.	Found, reduced.
SiO_2	37.39	36.94
Al_2O_3	12.67	12.57
Ag_2O	43.23	43.47
N_2O_5	6.71	7.02
	100.00	100.00

The thallium chabazite is also a nitrate derivative, but the transformation was less complete than in the case of the silver salt. It corresponds to

$$3Al_2Tl_3(Si_3O_8)_2NO_3\,;$$

$$1Al_3Tl_3(SiO_4)_3.$$

Reducing the actual analysis by exclusion of water, computing CaO and Na_2O into Tl_2O and recalculating to 100 per cent., we have

	Calculated.	Found, reduced.
SiO_2	28.47	28.46
Al_2O_3	10.38	10.58
Tl_2O	57.49	57.48
N_2O_5	3.66	3.48
	100.00	100.00

These agreements are strikingly close, and establish, with a high degree of probability, the existence of the chlorine or nitro-derivatives represented by the formulæ. These substances, sometimes mingled with the normal derivatives, seem to exist in the residues obtained in the experiments. Even the barium chabazite "*C*" agrees roughly with the composition.

$$Al_4Ba_3(Si_3O_8)_4Cl_2 + Al_4Ba_3(SiO_4)_4Cl_2\,;$$

although much weight cannot be given to this coincidence. It may be noted, in passing, that Weyberg[1] has recently described compounds obtained by fusing kaolin with calcium chloride or bromide, to which he assigns the formulæ

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[1] Centralblatt Min. Geol. Pal., 1904, p. 729, and 1905, p. 138. The calcium chloride derivative had previously been noted by Gorgeu, Bull. Soc. Min., 10, 276.

$$6SiO_2.6Al_2O_3.12CaO.4CaCl_2;$$

and

$$5SiO_2.8Al_2O_3.12CaO.4CaBr_2.$$

These substances, however, have no apparent relation to our zeolitic derivatives, nor can they be simply formulated structurally. By fusing kaolin with strontium and barium chlorides he obtained the basic salts

$$4SrO.4Al_2O_3.7SiO_2;$$

and

$$4BaO.4Al_2O_3.7SiO_2;$$

which, in their physical properties, resemble nepheline.

For thomsonite, a silicate of quite different ratios from stilbite and chabazite, three derivatives have been prepared. The analyses are as follows:

	Steiger. Thomsonite.	Steiger. NH_4 salt.	Steiger. Ag salt.	McNeil. Na Salt.
SiO_2	41.13	42.65	34.99	44.00
Al_2O_3	29.58	31.34	24.02	32.85
CaO	11.25	9.23	7.54	2.75
Na_2O	5.31	2.48	.74	18.32
$(NH_4)_2O$	——	4.08	——	——
Ag_2O	——	——	24.32	——
H_2O	13.13	10.40	8.39	——
Cl	——	——	——	3.01
	100.40	100.18	100.00	100.93
Less O				.68
				100.25

From these the subjoined empirical formulæ follow, calculated for the anhydrous compounds.

Thomsonite	$R_{838}'Al_{847}Si_{1000}O_{3689}$.
NH_4 salt	$R_{796}'Al_{863}Si_{1000}O_{3693}$.
Ag salt	$R_{864}'Al_{806}Si_{1000}O_{3641}$.
Na salt	$R_{911}'Al_{879}Si_{1000}O_{3730}Cl_{116}$.

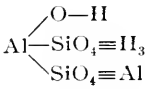
The thomsonite itself conforms sharply to the normal ratio of $Al_3Na_3X_3$, in which X_3 represents $SiO_4 + Si_3O_8$. The proportion of Si_3O_8 however, is only one eleventh. The sodium derivative, which contains chlorine, appears to resemble the compounds derived from stilbite and chabazite, and may be regarded as very near the mixture

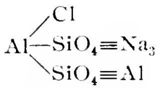
$$4Al_2Na_3(Si_3O_8)_2Cl,$$
$$10Al_2Na_3(SiO_4)_2Cl,$$
$$25Al_3Na_3(SiO_4)_3;$$

which may be compared with the *reduced* analysis as follows:

	Calculated.	Found, reduced.
SiO_2	43.53	43.75
Al_2O_3	32.02	32.68
Na_2O	22.11	21.26
Cl	3.03	2.99
	100.69	100.68
Less O	.69	.68
	100.00	100.00

The agreement is as close as we could reasonably expect it to be, when we remember that the substance was formed at a temperature above the melting point of sodium chloride. One of the chlorinated molecules, it may be observed, is curiously like kaolin in structure, as a comparison of the probable formulæ will show.


Kaolin.


New compound.

These expressions have the merit of suggestiveness and may lead to new experiments by and by. The compounds should be derivable the one from the other, if the comparison between them is really sound.

In addition to the derivatives mentioned in the foregoing pages, Mr. Steiger has prepared ammonium, silver, and thallium natrolite, thallium mesolite, ammonium and silver scolecite, ammonium leucite, ammonium heulandite, etc. These products are sufficiently described in Survey Bulletins 207 and 262.

PROCEEDINGS

OF THE

WASHINGTON ACADEMY OF SCIENCES

VOL. VII, PP. 267–275. PLATE XII. JULY 24, 1905.

SIMULTANEOUS JOINTS.

By GEORGE F. BECKER.

JOINTS are almost universally distributed over rock exposures, and they are so highly significant that the interest attaching to them can never be exhausted. In the present paper I propose to discuss systems of joints of simultaneous or almost simultaneous origin, not with the idea of developing any new principles, but in order to call the attention of geologists and mining men to some details which have been insufficiently considered although they are of importance in reading the record of mining districts and tectonic belts.

Most fine-grained solids which are capable of rupture under given conditions behave similarly. Exceptionally plastic or ductile bodies, like aluminium and pure lead, can scarcely be broken by crushing. Some substances again show different resistances in different directions; for example, single crystals, like those of quartz, and masses with a laminar structure, such as slate. But massive rocks in large masses, as well as many limestones and sandstones, cast iron and some forms of steel, are to all intents and purposes isomorphous in that they display practically equal resistances in all directions. Such materials when subjected to forces obey the same laws as softer solids, such as plaster of paris, wax and "ceresin" (the trade name for a mixture of crystalline paraffines derived from ozokerite). It would indeed be perplexing if large blocks of materials composed of small crystalline grains irregularly oriented, did not show common properties.[1] Even clay, so little moistened as to be "stiff" acts as if it were a true solid.

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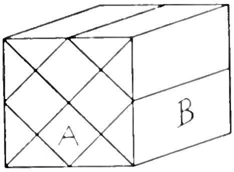
[1] With glasses, a class of bodies which needs more study than it has received, I shall not deal in this paper.

These isomorphous or pseudo-isomorphous substances rupture in 2 ways, both of which may often be illustrated in the same experiment. One species of fracture takes place by tension, and is usually characterized by sharp curvatures and uneven surfaces; the mass is *torn* asunder. The other method of fracture is by "shearing motions," due to pressure; the mass is *cut* to pieces by surfaces which are often, and in fact characteristically, flat and smooth.

Persistent joints and systems of joints are due to pressures while the partings between columnar basalts and the very similar cracks in drying mud arise from tension. In mining districts tension cracks often appear as a subordinate phenomenon where faulting has forced apart slaty walls, leaving splinters attached to both sides of a fissure which itself arose from pressure, and I have even seen similar occurrences along the crevasses of a glacier. So, too, when a cylinder of relatively mild steel is crushed, the bulging edge of the mass may show meridional tension cracks due to the increase of the equatorial periphery, even when the interior displays diagonal fracture. The behavior of cylinders, however, has some peculiarities which will be mentioned presently.

Rocks are often ruptured without much preliminary deformation, and it is easiest to begin with the hypothesis that the deformation is negligibly small. The effect of larger deformation can be traced after the principal characteristics of rupture have been examined. It is also convenient to consider first of all a cubical or at least a rectangular mass.

Suppose then that a cube of rock (shown in Fig. 1, Pl. XII) is subjected to a perpendicular and evenly distributed force acting on its upper and under surfaces while the face *A* and that opposite to it are supported in such a way as to obviate rupture. Then the effect of force will be to produce ruptures along planes perpendicular to *A* and inclined in opposite directions at an angle of 45° to the line of force. Two systems of joints will result forming angles of 90° to one another on *A* or on sections parallel to this face. On the face of the cube marked *B* and that opposite to *B*, the traces of these joint planes will be horizontal straight lines, while on the surfaces on which the forces



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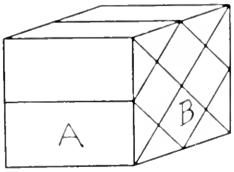

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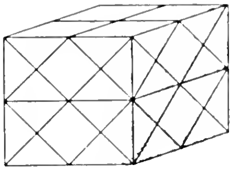

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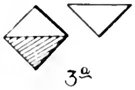

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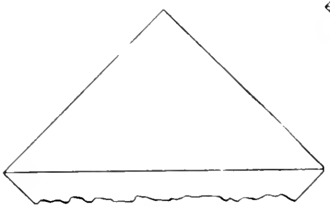

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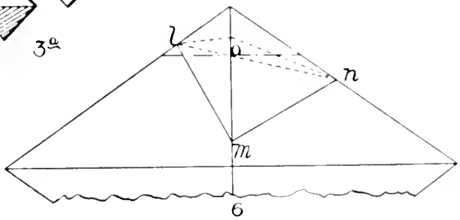

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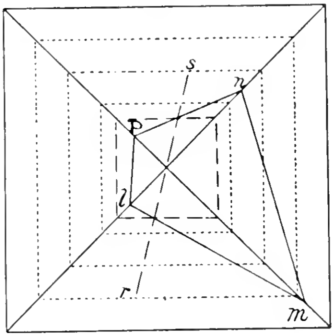

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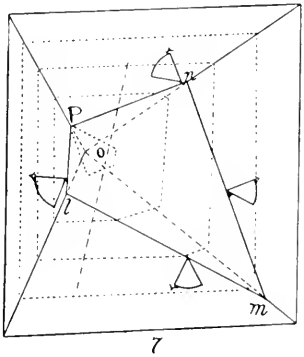

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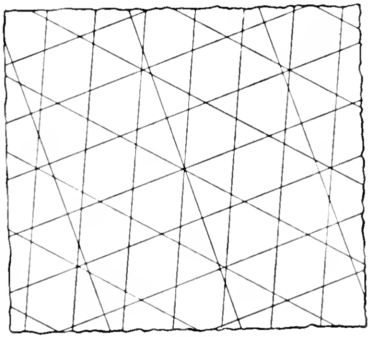

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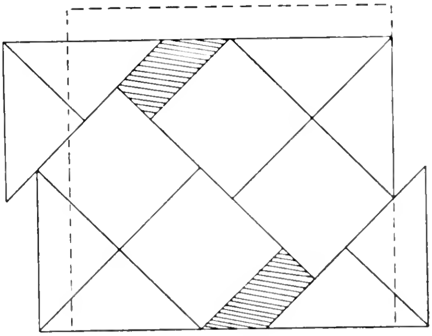

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act, that is to say, on the top and the bottom of the cube, the traces of the joints will be parallel straight lines perpendicular to *A*. By these means the cube will be divided into a number of square prisms so placed that the diagonals of the squares are either horizontal or vertical.

It has come to be pretty generally recognized that two systems of joints such as those described may be produced by a single force acting at an angle of about 45° to each system. If the deformation antecedent to rupture were of sensible amount, the joints would make angles of somewhat more than 45° with the line of force.

It is not so generally understood that 4 or even more than 4 systems of joints may be due to a single force. This case is less common than that of a smaller number of partings, and is usually confined to limited areas, but it is not infrequent, particularly in the disturbed regions which ores so much affect.

Imagine a second cube, shown in Fig. 2, similar in all respects to the first excepting that the faces *B* and its opposite are supported instead of faces *A* and that opposite to it; then of course the result will be the formation of prisms whose square cross sections will be visible on *B* instead of on *A*. If on the other hand the cube is not supported on any side, or if the resistance perpendicularly to the line of force is uniform, then these 2 systems of rupture will take place simultaneously, so that on both *A* and *B* there will be systems of cracks at 45° to the line of force intersecting one another at 90°, while each of these faces will also show horizontal cracks. By these means, the cube will be divided into octahedral and tetrahedral blocks as indicated in Figs. 3 and 3*a*. Such rupturing can be and has been experimentally verified, for instance by Daubrée; but I know of no experiments so perfect as instances which may be observed occasionally in rock exposures.

In experiments on cylinders, the lines of rupture are often found to be conically disposed, and this mode of rupture requires explanation, especially as corresponding phenomena are so rare in nature that I have never met with them. When a cylinder is linearly compressed (say vertically) between masses of much more rigid material, the cylindrical form is not preserved, the mantle of the cylinder expanding to the shape of a barrel. The reason for this is that intense friction is produced by the effort of the end surfaces to expand in contact with the rigid planes exerting the vertical pressure. I have experimented somewhat elaborately on the character of this strain and have determined the position of the strain ellipsoid at 64 points on a vertical cross-section. The greatest axis of the ellipsoid lies in the plane passing vertically through the center of the cylinder, but it is not horizontal; it is inclined to the horizontal at an angle which varies with the distance from the central vertical axis of the barrel-shaped mass. The least axes of the ellipsoid also lie in the vertical central cross-section of the mass and the surfaces[1] of "maximum tangential strain" are conoidal with their apices in the axis of figure. It is along these latter surfaces that rupture due to pressure must occur if at all, as I showed long ago. At any one point of such a cylinder the strain is homogeneous and exactly comparable to that in a uniformly strained cube. The peculiarity of experimental results on cylinders lies in the radial symmetry of the stress system.

If it were possible to crush cylinders between frictionless surfaces, so that the deformed blocks would retain a uniform diameter, the strain ellipsoids would have 2 equal horizontal axes, and, if the mass were ideally homogeneous, it is difficult to see what would determine the position of the ruptures. But this is not an important question. In real matter the resistance could not be exactly the same in all directions and 2 systems of joints would form as in the cube. In a cubical mass, or in one of square cross-section, the cracks will be perpendicular to the sides of the cube as explained above, because this is the position of least resistance, or because a unit area of rupture in this orientation goes farthest towards relieving the strain in the yielding mass.

In the lithosphere, when crushing or jointing takes place, the masses exerting the pressure are almost invariably little more resistant than the rock which is ruptured. It is very seldom,

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[1] U. S. Geol. Surv. Bull., 241, 1904. The surfaces of rupture are such as would be obtained by rotating Fig. 14 of that bulletin about its smallest diameter, but if the deformation were small these surfaces would be indistinguishable from right cones.

therefore, that those features of experiments are observable in nature which depend on great differences in strength between the material tested and the apparatus used in testing.

In cases of uniform lateral resistance then, at least 4 systems of joints may form simultaneously as the result of the action of a single force, separating the rock into octahedrons and tetrahedrons. Very minute differences in resistance would of course modify the development of the octahedral faces, but the 4 sets of planes at least would be, and often are, perfectly distinct.

In experiments the 4 surfaces are so oriented as to be readily distinguished, but in nature such orientation is relatively rare. Tectonic forces are not usually exactly horizontal or exactly vertical, and the exposures due to erosion or other causes are generally inclined surfaces. Now, granting the simplicity and symmetry of the fissuring, it is not at once evident how the joints would be distributed on a plane taken at random through the jointed mass. It is really an easy matter to project the fissure systems onto a random plane, and requires only the application of rudimentary descriptive geometry; but the step has not heretofore been taken, while it is interesting to compare the results of the process with natural examples. The plots also indicate how observations on a random plane may most simply be dealt with when it is desirable to reduce field data to a symmetrical orientation and to find the line of force.

On account of its bilateral symmetry the octahedron gives a convenient starting point for constructing a random section. This octahedron will not be a regular one, inasmuch as the angle between 2 planes taken over the coign will be a right angle, and the 8 triangles of the octahedron will therefore not be equilateral.

Fig. 4 shows such an octahedron so drawn as to expose to view only 2 of the triangular faces. Fig. 5 shows the same octahedron in plan and Fig. 6 in elevation, 4 faces being visible.

In order to display the fissure systems of the jointed mass taken on a random plane, any 3 points on the edges of the octahedron may be selected in Fig. 6, such as *l*, *m*, *n*. These points of course fix the plane. By evident and familiar methods the random plane can now be brought into the plane of the paper as shown in Fig. 7,[1] where also the direction and amount of dip of the 4 surfaces is shown as determined by an easy construction. Finally from the data of Fig. 7 and the hypothesis that the fissures are evenly distributed in space, it is possible to display the traces of the joints on the random plane as shown in Fig. 8.

Every observer who has paid attention to systematic jointing, will recognize the similarity between Fig. 8 and certain field occurrences; it is noticeable, too, that the effect produced by Fig. 8 is much more complex than the indications of Figs. 1 and 2 might lead one to expect. Such a joint system as is displayed in Fig. 8 does not ordinarily extend over any large region of country and the reason is that in nature, as a rule, the unequal support afforded by surrounding rock masses is sufficient to suppress one or more of the joint systems. As pointed out above, it is only when the resistance perpendicular to the line of force is the same in every direction that all 4 systems of joints will appear. On the other hand, even more complex systems are sometimes found locally developed for reasons which will be set forth a little later.

The process of construction outlined can be reversed, so that if the spacing and dip of the fissures on the random plane were given, the quadrangle of Fig. 7 could be drawn and the position of the octahedron, or the line of force, determined. There are natural cases in which this reduction would be instructive.

In the construction of Fig. 8, it has been assumed that the permanent strain at rupture was insignificant and, on this hypothesis, the faces of the octahedron are isosceles triangles with one angle of $70° 32'$ ($\cos^{-1} 1/3$) and 2 equal smaller angles.

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[1] Transfer the intersections of the random plane from Fig. 6, Pl. XII, to Fig. 5, Pl. XII; draw also in 5 a square (parallel to the plane of 5) which will contain the point at which the random plane intersects the axis of the octahedron. Then the line *rs* is common to 5 and 7 and rotation of 5 about the line *rs* yields 7.

In constructing Fig. 7 it is necessary to have a vertical section through Fig. 5 perpendicular to *rs*. In finding the spacing for Fig. 8 it is convenient to have 2 other vertical sections of 5, one along the line *pm* and the other along *ln*. It is unnecessary to state that computation might be substituted for construction if a high degree of accuracy were called for.

If permanent deformation of notable amount preceded rupture, the single angle would be greater than 70° 32′.

In the foregoing, it has been supposed that the joints are mere cracks and that no measurable amount of motion occurs on any of them. This is often approximately true in nature. The throw of the faults produced on the joints is sometimes so small as to be microscopic, and I have measured great numbers of such dislocations which were expressible only in hundredths of an inch. Nevertheless, it remains true that a joint does not form except in obedience to a tendency to faulting. When a block of any material is squeezed between a plunger and an anvil, it does not crack until it can yield no further without cracking. In other words, rupture takes place in order to permit of a closer approach between plunger and anvil than is consistent with the continuity of the block subjected to experiment. These cracks undergo a certain throw in the very act of forming. In order to perceive the nature of the dislocation it is best to assume that it reaches a considerable amount. I will suppose for example that the shortening of a ruptured block is 10 per cent. Then the dislocation must be of the type represented in Fig. 9, though a certain variety in the disposition of the residual fragments is evidently possible. Now, Fig. 9 shows several large faults, and the shortening evidently could not have been achieved without these or equivalent dislocations.

It is often assumed that when one fissure faults another the latter is the older, but this inference is not justifiable and they must often be of exactly the same age. Very frequently interlacing quartz veins may be studied in which the quartz is continuous from one system of ruptures to the other, and in which there is every indication that the ore was deposited at a single epoch. Such instances show no slickensides within the veins, but even when there are slickensides these may possibly be due to fresh movements on the old surfaces after ore deposition is finished. Of course I do not mean to deny that cases occur in which some veins are younger than others with which they are associated. I merely mean to warn colleagues against hasty inferences in regard to the relative age of veins.

If such a system of dislocations as is shown in Fig. 9 were to be produced under any considerable external pressure, it is manifest that the several residual fragments might be pressed against one another with very great force. In such a case the mere grinding action accompanying the dislocation would tend to produce further ruptures in the residual fragments. It is not easy to work out a satisfactory theory of the distribution of such secondary fractures. It is fairly evident, however, that in an extensive complex, of which Fig. 9, Pl. XII, may represent a small portion, there is likely to be a repetition of identical conditions, so that many separate blocks will be similarly situated with reference to their neighbors. If secondary rupture takes place, such blocks will be similarly affected and their fissures will be parallel, but probably not continuous throughout the mass. The more numerous the groups of similarly oriented blocks after the original jointing, the more numerous will be the systems of blind secondary joints. These latter may indeed be regarded as subsequent to the original joints, yet the difference in age may be only a second or two and the brevity of the interval should be taken into account in reading the history of the district.

To me it appears questionable whether in a region once jointed by a system of forces, the application of a new system of forces could produce a fresh set of joints systematically arranged. The resistance of a jointed rock mass is so extremely unequal in different directions, and so small in many of them, that fresh movements on the old joints or the reduction of the formation to a chaotic rubble seems more probable than anything comparable with renewed systematic jointing. Thus forces acting on a brick wall usually produce cracks which follow the joints between bricks, and if bricks were not designedly laid so as to "break joints," and carefully cemented besides, cracked bricks in damaged walls would be still rarer than they are.

Fig. 9 shows that a cube fractured by pressure must occupy a larger volume than it did before fracture. Following the indications of Fig. 9 the lateral expansion would amount to over two-tenths when the vertical diminution of height is one-tenth, so that the crushed cube under these conditions would occupy a volume nearly a third greater than before rupture. It follows then that in a rock mass which has been jointed there must be an increase of volume which cannot be without geological importance. There are various ways in which this volume might make itself manifest. If the material surrounding the crushed mass does not yield, and if one surface of the crushed mass coincides with the surface of the earth, then the area affected by joints must rise regularly or irregularly above this level. If on the other hand, the space subjected to crushing is so placed that a vertical swelling is impossible, the masses surrounding the crushed volume must be driven back and thus either deformed or crushed. Now nearly all rocks are jointed, and the total increment of volume over a large area affected by joints is likely to find expression in technically important faults or even in tectonic movements.

Of course rock masses are usually supported on all sides, or on all sides but one, by masses presenting great resistance either to deformation or to rupture. This would not obviate the tendency to the formation of joints on systems like those represented in Figs. 1, 2 and 3, but it might prevent, or partially prevent, the realization of these ruptures. In such a case what would be the internal changes affecting the rock masses? Evidently there would be relative movements along the lines on which joints tended to form, but since no opportunity or an insufficient opportunity was afforded for an increase of volume, few joints or none at all would result. In the extreme case, the result would be deformation without rupture. In so far, however, as the actual relative motion of the particles exceeds the limit of elastic recovery, it is natural to suppose that cohesion along these surfaces would be diminished and that the mass would manifest this alteration of structure by splitting more readily in these directions than in others bearing no relation to them. It is to such a weakening along the surface of relative motion that I have ascribed the origin of schistosity and slaty cleavage, subjects which I have discussed at quite sufficient length elsewhere.

PROCEEDINGS

OF THE

WASHINGTON ACADEMY OF SCIENCES

VOL. VII, PP. 277–282. PLATE XIII. JULY 24, 1905.

A FEATURE OF MAYÓN VOLCANO.

By GEORGE F. BECKER.

THE U. S. Coast and Geodetic Survey in March, 1905, published Chart No. 4,237 showing Mayón Volcano and neighboring portions of Sorsogón on a scale of 1 to 40,000. It gives the elevation of the summit as 7,943 feet, which is a little lower than the determinations of Jagor and Abella. About the time that these surveys were being made in 1901, Mr. Henry Gannett was in the neighborhood and took a small photograph of the volcano from the bridge at Legaspi. This point is 8½ miles, measured horizontally from the summit of the mountain, which bears north 30° west from the bridge. There being water in the foreground of the photograph, it is possible to determine with a close degree of accuracy the direction of a level line, and therefore to compute or construct elevations at the distance of the cross-section of the volcano. It may thus be determined that, on the scale of the photograph, 26 millimeters in the perpendicular through the summit of the volcano are equal to 7,943 feet, or 305.5 feet per millimeter.

The most thorough investigation of the lava of Mayón was published in 1881 by Mr. K. Oebbeke, who had at his disposal the lithological collections made by Carl Semper. Mr. Oebbeke pronounces the rock an olivinitic augite andesite. Eruptions at Mayón are of very great frequency. They occur every couple of years and oftentimes last several months. Many of these outbursts have been described and they all appear to belong to a single type. Large quantities of ash are ejected, but the ejecta are by no means all ash. Lava streams descend the side of the mountain and have more than once been known to reach the sea. The last eruption in which this happened was in March, 1900, and the account of it given by Colonel Walter Howe appears in the Census of the Philippine Islands, Vol. 1, p. 223, 1905. Besides the fairly solid rock masses represented by lava flows, it may be considered tolerably certain that, as elsewhere, volcanic ash, wet by the showers accompanying eruptions, cements into a firm tuff. In all probability, however, the actual smoothness of external form of the volcano is due to a mantle of ash which dresses up the surface, filling out inequalities, increasing the steepness wherever possible, and producing a conical figure very characteristic of a large class of volcanic cones. This shape is still recognizable and fairly well preserved in mountains like Shasta and Ranier. One of the most perfect examples in the world is the famous Fujisan of Japan, which, however, has had no eruption since 1707. Evidently, had Fujisan been entirely loose ash, the erosion and gales of 2 centuries would have seriously impaired its beauty, and since it is still so perfect, the material must offer considerable resistance to the forces of degradation. Mayón is even more perfect than Fujisan, because of its frequent eruptions.

This characteristic form of volcanic cone is rarely associated with rocks of an exclusively basaltic character. The Hawaiian volcanoes emit basalts which flow for immense distances before final solidification, and as a consequence, the accumulations of lava aggregate to dome-like shapes the height of which is small as compared with the mass and with the diameter. Small cinder-cones of basaltic ash, however, sometimes occur which are recognizably of the same geometrical type as Fuji.

Mere inspection shows that these beautiful cones have unbroken outlines, and observation indicates that the characteristic form is due to ash. Hence the mathematical problem of the figure appears to be this : To find the loftiest figure of given volume and continuous curvature which can be built up of successive showers of ash, each ash layer being supposed to become indurated after its deposition. In dealing with this problem, the crater may be supposed of infinitesimal size.

In 1885, I published a theory of volcanic cones, and in 1898 gave a fresh demonstration of the formula deduced.[1] According to this theory, the outline of a volcano should be represented by the hyperbolic sine curve, or

$$\frac{y}{c} = \frac{e^{x/c} - e^{-x/c}}{2}$$

where x is the distance below the summit, y the radius of the horizontal cross-section and c a unit of measurement which is in fact twice the height of a column of the lava which would just support its own weight.

Mr. Gannett's photograph, together with the elevation of the mountain given by the Coast Survey, enables me to compute the particular value of c for this volcano. If the outline of the mountain were perfectly smooth, the value of c could be determined for any point upon the slope.[2] The actual outline in the photograph, although remarkably regular, is not absolutely smooth, and therefore this means of ascertaining c affords only an approximation. I thus found that c must be between 8 and 9 mm. On plotting the hyperbolic sine curve for $c = 8.8$ mm., it appeared that this value was decidedly too large, while a similar trial showed that 8.3 was decidedly too small. The third trial, taking $c = 8.6$ mm., gave a curve almost indistinguishable from the natural outline. Both the photograph

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[1] Amer. Journ. Sci., vol. 30, 1885, p. 283. U. S. Geol. Survey, 18th Ann. Rep., Pt. III, 1898, p. 20.

[2] If ϑ is the angle which the curve makes with the axis,

$$c = \frac{y}{\sqrt{\tan^2\vartheta - 1}}.$$

The angle at the summit when the crater is infinitesimal, or 45°, is the maximum possible angle of rest. If W is the resistance due to friction and N the normal pressure, while ρ is the angle of rest,

$$\tan \rho = W/N.$$

Now the resistance, W, cannot possibly exceed the normal pressure which excites it, so that the limiting value of W/N is 1 or $\rho = 45°$.

The meaning of the constant c is readily grasped by considering that at a great distance from the summit the theoretical volcanic cone sensibly coincides with the logarithmic column

$$y = Ae^{x/c}$$

and here the maximum possible value of c is twice the height of a prismatic column of the material which will just support its own weight.

and the hyperbolic sine curve for this value of c are given in the first illustration, Pl. XIII, Figs. 1 and 2. The easiest method of making a comparison is to trace the mathematical locus on a bit of thin paper and lay it over the picture of the mountain. The value of c thus found corresponds to 2,627 feet.

In 1885, I computed the value of c from 4 surveyed cross-sections of Mt. Shasta, finding for that case a value of 2,640 feet, while for the neighboring smaller mountain, Sugar Loaf, I got 2,560 feet. It is certainly a very remarkable circumstance that a photograph of Mayón gives a value of c only 13 feet lower than that found for Shasta, or to within a half per cent. the same value. The rocks of Shasta are chiefly andesite, largely olivinitic, associated with some basalt, and therefore extremely similar to those of Mayón. It would appear also that, in spite of the great variation which the manner of cooling and other accidents attending eruption must induce in the continuity and grosser physical qualities of the lava, the mean strength of the rock at these two localities, distant from one another so many thousand miles, is almost exactly the same.

While the similarity in strength and in lithological composition of Shasta and Mayón is very noteworthy, it does not follow that all andesitic volcanoes would show similar values of the constant c. The rock of Shasta is chiefly of the rough porous type called by Gümbel trachytic andesite and by me asperite. On the other hand, Fujisan appears to consist of pyroxene andesites of the denser basaltic type. Professor Milne applied my theory to this famous mountain and found as the mean of several determinations from photographs and surveys $c = 4,490$ feet.[1] I reached substantially the same value by constructing a cross-section of Fuji from the topographical map issued by the Geological Survey of Japan in 1887. The section was taken along a line bearing N. 36½° E. and gave $c = 4,462$ feet. This section and the theoretical curve are shown in Text-fig. 1 and agree most satisfactorily.

I have from time to time met with a great number of photographs of volcanic cones, especially in Central and South America, which agree admirably in form with the hyperbolic

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[1] Trans. Seismological Soc., Japan, Vol. 9, Pt. II., p. 180, 1886.

Photo by Henry Gannett

FIG. 1.

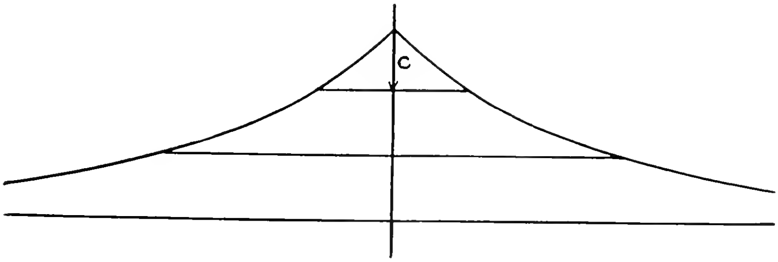

FIG. 2.

Mayón Volcano.

sine curve. As a rule, however, the height of the summit of these mountains above the camera is not known, and there is insufficient proof that the camera was properly leveled. It is to be wished, in the interest of vulcanology, that observers taking photographs of such cones would carefully level their instruments and state the exact locality from which they were taken, in order that when the topography of the regions is better known, it may be possible to determine exactly what the value of *c* is for each particular case.

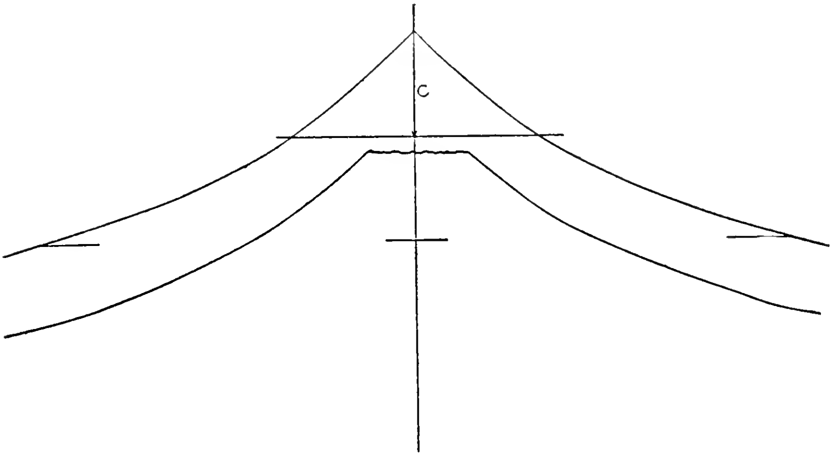

FIG. 1.

Closely allied to the form of volcanic cones is that of the small "driblet cones" of J. D. Dana. He describes them as forming about small apertures whence the escape of vapors produces a throw of fiery spray. The drops fall back upon one another, becoming soldered, because still partially melted, and gradually build up the driblet cone.[1] He was able to observe the process in Hawaii.

While in a cone of the Fuji type the solid ejecta falling on the steep slopes must roll or slide down the declivities to a greater or less extent, it is possible to imagine the several particles so sticky as to stay where they fall and this seems actually to be the case when driblet cones form. The drops from a vertical spray, or the grains from a vertical sand blast of small

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[1] Characteristics of Volcanoes, 1890, pp. 17, 71, 85, 160.

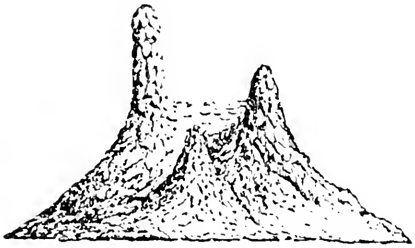
diameter, would strike like bullets on a target of which the bull's eye represents the orifice of the spray. The distribution of the mass as a whole would then be given by the well known probability curve, but the geometrical configuration of the aggregation would be somewhat different. Taking the constant of the probability curve as equal to $\sqrt{\pi}$ so that the maximum ordinate, w, becomes unity, the equation of that curve is

$$w = c^{-\pi r^2}.$$

For the solid figure representing the driblet cone, it is easy to see that if z is the vertical ordinate $2\pi r dr \cdot z = w dr$ or

$$z = \frac{1}{2\pi r} \cdot c^{-\pi r^2}.$$

This I take to be the most natural form of a driblet cone. If perfect, it would be a slender spine reaching an infinite height though of finite volume, but wind or seismic jars would prevent its growing very high, even if the molten spray spurted to indefinite heights and the orifice were of infinitissimal diameter. Hence the column in nature would be truncated and would doubtless be surrounded by a talus. It is so represented in fig. 2*b*, while one of Dana's figures is reproduced in 2*a*.



THE CATHEDRAL: DRIBLET-CONE, 1864.

FIG. 2*a*.

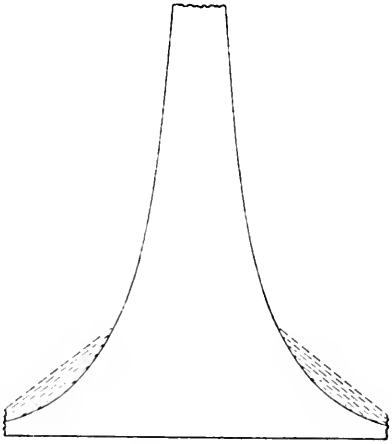


FIG. 2*b*.

It is imaginable that the famous spine of Pelée might have been formed in this way, but the evidence points rather to Mr. Lacroix' hypothesis of extrusion, something as a lead rod is forced out of a cylinder by pressure.

PROCEEDINGS

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VOL. VII, PP. 283–288. JULY 24, 1905.

THE LINEAR FORCE OF GROWING CRYSTALS.

BY GEORGE F. BECKER AND ARTHUR L. DAY.

THAT growing crystals exert a linear pressure in the direction in which they grow appears to have been first observed by Dr. Jean Lavalle in 1853.[1] He noticed that crystals in saturated solutions increase most rapidly on their under surfaces, so that the first portion of the crystal to form is driven upward by the forces involved in the crystallization. This result was denied by Kopp, but has since been confirmed by various authorities, including Lehmann, who gave an account of the matter in his work on Molecular Physics[2] in 1888. The evidence in favor of Lavalle's view includes many familiar phenomena like the raising of crusts of earth by frost, the appearance of which must be familiar to everyone in high latitudes. Perhaps a still better one, to which reference has not been made, is the fact that fence-posts are very apt to be gradually drawn out of their beds by recurrent frosts.

No quantitative experiments have been made, so far as we know, on this subject, which seems to have excited very little attention for the past twenty years.

In the study of ore deposits, occurrences are sometimes observable in which crystals have exerted a very considerable force; for example, it was long ago noticed that crystals of pyrite form in slates in such a way as to drive apart the laminæ of the rock without any sensible or traceable deformation of the crystals.[3] More important evidence of similar action is found

[1] Compt. Rend., vol. 36, 1853, p. 493.

[2] Vol. 1, p. 345.

[3] U. S. Geol. Survey, 16th Ann. Rep., Part III, p. 287.

in some of the deposits of so-called ribbon-ore. In the gold belt of California this term, often used in a different sense, is applied to designate quartzose ores containing thin, parallel laminæ of slate. It has often been supposed by geologists and mining engineers that the mechanics of this form of deposit consists of a preliminary faulting in the slate, the more or less irregular surfaces of which were forced apart by undulations of or projections from the surfaces of cleavage followed by a quiet deposition of quartz from solution. In some relatively rare cases, however, it can be shown conclusively that the distribution of the slate is not due to faulting. Occasionally the slates contain grit bands which cause a local, sharply marked deflection in the cleavage of the slate; and in the Mother Lode cases have been observed where such marked laminæ have been driven apart normally by some cause or other, leaving room between them for combs of quartz crystals in layers which sometimes reach 6 inches in width. When such occurrences cannot be accounted for by faulting, the inference is almost unavoidable that the laminæ have been driven apart by the force of the growing crystals, the axes of which stand sensibly at right angles to the planes of the laminæ. This hypothesis, however, ought not to be accepted without the most careful scrutiny, for it implies force of great intensity. If the laminæ have been forced apart in this way, then the whole lode must have been increased in width by the same means; and when the sum of the distances between the slate bands is taken into consideration, this indicates a force of orogenic intensity and of really stupendous aggregate amount. The Mother Lode in California is something like 150 miles in length, and has been explored to a depth of several thousand feet. Its width is often several hundred feet, and that such a cleft could have been opened or considerably increased in width through the force of growing crystals is certainly hard to believe.

Experiments on the subject were instituted immediately after the first observation of this kind was made. The first effort was directed to ascertaining whether crystals of a substance like alum would raise a glass plate beneath which a saturated solution of the salt had been introduced. The experiment was immediately successful, so that after a few hours a measurable rise in the glass plate was detected.

Having established in principle that a considerable load could thus be raised, the attempt was made to develop well formed crystals of alum and to measure the load which they were capable of raising per unit of lifting area. After the technique of these experiments had been mastered, it was found practicable in a saturated solution of constant temperature to grow clear crystals a centimeter in diameter which would raise a weight of a kilogram through a distance of several tenths of a millimeter. The crystal was placed upon a piece of plate glass in a beaker containing saturated solution of the same material, and loaded as desired. Knowing the weight raised, it appeared an exceedingly simple matter to determine the force required, since it was only necessary to ascertain the actual area of contact be-

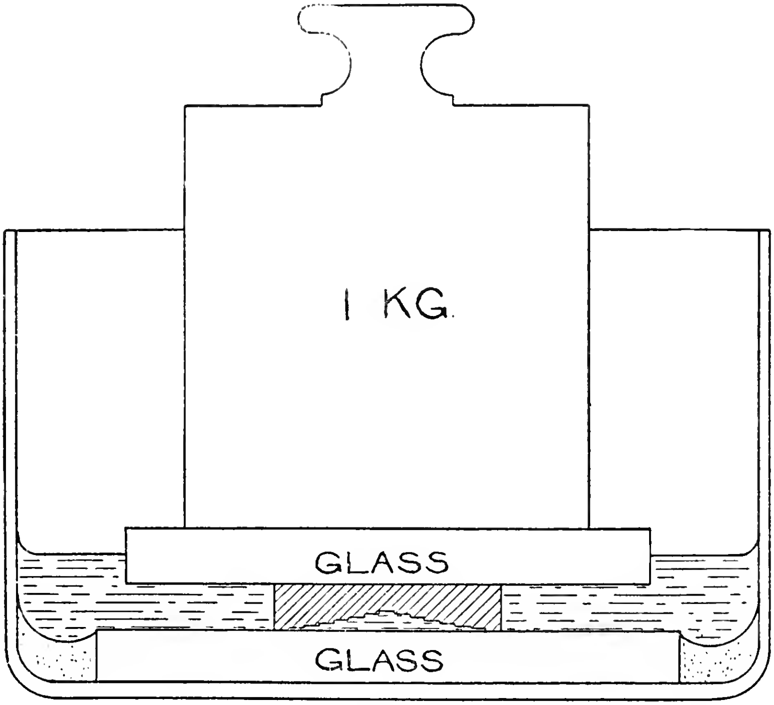

Fig. 1.

tween the weight and the crystal. Here, however, an unexpected difficulty was encountered. The face of the crystal in contact with the lower surface of the vessel is not plane and does not even distantly approach this configuration. On the contrary, a terraced cup forms below the crystal so that the bearing surface remains a mere edge throughout its growth. The accompanying figure may serve to give a fair idea of a section through the crystal at any time during its growth.

The closer the examination made of these cupped faces the smaller the actual bearing surface was found to be. One method of determining this area is obviously to print it off on a piece of paper, but it was found that the edges were often so fine that the printed lines appeared several times broader than the true edge. The process finally adopted was this: A fine micrometer screw was mounted vertically so as to carry the crystal downward in a motion accurately parallel to itself. Chlorophyll made up with fat was selected as printing ink. It gave a good color in extremely thin layers, showed no disturbing capillary action while the imprint was being made, and exerted no solvent effect upon the crystals. A very thin coating of this mixture upon bristolboard made a good inking pad. No paper was found sufficiently hard and flat to take the impression accurately, and our ingenuity was considerably taxed to find something which would do so; finally we hit upon the following device: White celluloid was dissolved in ether and alcohol and flowed upon a glass plate somewhat as a photographic plate is coated. When the volatile solvent had evaporated a level surface of opaque celluloid remained behind which was extremely smooth and flat. On this surface prints of the crystals could be taken, portions of the impressions often being so fine that they quite escaped notice unless seen through a reading glass. They would defy reproduction in illustrations.

The measurement of the minute areas thus recorded is a matter of great difficulty and uncertainty, and the force per unit area which the crystals exert is, therefore, hard to estimate. It was at once evident that it amounted to many pounds per square inch, and as observations multiplied, it became reasonably certain that it is actually of the same order of magnitude as the ascertained resistance which the crystals offered to crushing stresses. Moreover, there is reason to believe that this area changes constantly as the crystals grow, and is less for a smaller load than for a larger one.

The upper contact surface of the crystal is also variable, but always much more perfect than the lower. Relatively large areas in perfect contact with the glass plate which supports the weight were frequently found by careful printing.

Following these determinations, confirmatory experiments were made upon other salts (copper sulphate, ferrocyanide of potassium, lead nitrate), the results being practically the same as those found for alum.

It is manifest that we here have to do with a force of great geological importance. If quartz, during crystallization, exerts a pressure on the sides of a vein which is of the same order of magnitude as the resistance which it offers to crushing, then this force is also of the same order of magnitude as the resistance of wall-rocks, and it thus becomes possible that, as indicated by observation, the Mother Lode and other great veins have actually been widened to an important extent, perhaps as much as 100 per cent., or even more, by pressure due to this cause. In mining regions the whole country is frequently intersected with systems of quartz veins. Some of these, of course, are of notable size and capable of being worked, provided the quartz is sufficiently rich; but many more, a number vastly in excess of the large veins, are thin sheets no thicker than a card, incapable of profitable exploitation by man, though there is little question that these tiny veins have often contributed the bulk of the gold to placer deposits. In such a country there is almost no limit to the effect which might be produced by the force of the growing crystals, and the displacement might readily be so great as to induce important new fissures or important renewed movements on old fissures.

Again, in a vein where auriferous quartz is being deposited, the growth of crystals may readily extend the space in which successive crops of crystals might grow, so that in certain cases (for instance on an inclined vein, like the Comstock Lode, near the cropping) the deposition of ore might continue almost indefinitely and the total deposit thus increase with time.

To what extent detailed observations will show a history of this kind for ore deposits, it is too early to say, but it is certainly worth while to draw the attention of geologists and mining engineers to the possibilities thus presented, and to dynamic conditions which may prove important as well as interesting.

To the physicist also the phenomena cannot be uninteresting. The power which roots exhibit to prize apart large building stones we are content to classify as "vital" and mysterious. We cannot so easily dispose of the similarly intense force with which, as it appears, inorganic molecules drive themselves into place, much as oakum is driven into the seams of a ship by a caulking iron. We hope to be able to continue this study at some future time.

PROCEEDINGS

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VOL. VII, PP. 289–299. PLATE XIV. JULY 24, 1905.

AN INTERESTING PSEUDOSOLID.

BY GEORGE F. BECKER AND ARTHUR L. DAY.

As is well known, Professor J. J. Thomson's investigations lead to the hypothesis that a molecule is a highly complex body consisting of great numbers of minuter particles called corpuscles, so that a molecule would be more nearly comparable to a swarm of meteorites than to, let us say, a planet. In considering this theory, it occurred to us that a model might be made from a mixture of liquid and gaseous ingredients, the physical properties of which would very closely resemble a homogeneous solid made up of such complex molecules. A bubble of soap solution, or any other viscid liquid would enclose great numbers of molecules of oxygen and nitrogen, all of them in rapid motion, and representing the corpuscles of Thomson's molecule, while the surface tension of the bubble itself would replace the attraction of the systems of corpuscles towards some interior point or points. The foam which accumulates in sheltered places on a rock-bound sea-coast, the beaten white of an egg or the whipped cream products of the pastry cook's art, represent very stable aggregates of such imitation molecules while they are of a size and character to admit of manipulation and study.

In order to obtain experimental evidence as to the properties of such foam, we prepared a prismatic mass of fine soapsuds and attempted by torsion to ascertain whether its behavior resembled that of a viscous liquid or a true solid. It is well known that the behavior of a twisted prism is very characteristic of the state of the matter composing it. A viscous liquid, such as sealing wax, under torsion moves in planes at right angles to the axis of torsion in such a way that each plane after torsion remains a plane. On the other hand, in a solid mass even of very feeble rigidity, surfaces originally plane and at right angles to the axis of torsion become warped or otherwise distorted surfaces after torsion. A prism of fine soapsuds was experimented upon by laying a fiber of silk around the periphery at right angles to the axis and then twisting the mass. The silk fiber immediately assumed the warped outline characteristic of solids and showed that, in this respect at least, the foam had the properties of a solid body.

After some qualitative trials, it seemed worth while to make at least an effort at measurement upon a solid of this character, one principal reason being that distinctly finite displacements (amounting to 30 or 40 per cent.) could very readily be obtained with it.

Plateau's solution was at first thought to offer the most promising material with which to prepare the pseudosolid, but we did not find it as serviceable for this purpose as it has proved to be for some others. We made up the solution from various olive oil soaps, then from " C. P." sodium oleates furnished by dealers, and finally with 2 preparations of very pure oleate made in the chemical laboratory of the Geological Survey. We were unable to verify Plateau's conclusion that increased purity produced increased tenacity of film; on the contrary, a plain solution of yellow soap mixed with glycerine in random proportions produced quite as rugged films. It was our experience, however, that all these films lost their toughness upon being beaten into foam, and that the prisms of such foam deteriorated so rapidly that no measurements could be made upon them.

We next turned to the white of egg, with which we attained a considerable measure of success. The white of a fresh egg (it is imperative that it be very fresh), in which about an equal volume of powdered sugar has been completely dissolved, can be beaten to an extraordinarily fine homogeneous foam from which prisms can be cut, mounted, and measurements covering several minutes made upon them without any considerable deterioration taking place. It also proved possible to strain these prisms to fracture and to lay them aside to dry, which they do with but little change of form, and to study or photograph these fractures at leisure. Many of these specimens resembled fractured close-grained rock so closely in the photograph as to be practically indistinguishable from it.

The apparatus with which the measurements upon these prisms were made was of extraordinary sensitiveness and admitted of very rapid manipulation.

A fine analytical balance was mounted with a mirror at the top of, and at right angles to, the beam, which could be observed with a telescope and vertical scale at a considerable distance, thereby furnishing a very sensitive measure of the motion of the beam. A die was then prepared with which cylinders of uniform size could be cut out of a mass of foam and deposited quickly upon one of the pans of the balance. The weight of the cylinder was compensated by an equal weight in the other pan. A glass bridge was then fixed in position over the foam cylinder and the pan raised until the upper surface of foam was in perfect contact with the glass bridge. The illustration (Text-fig. 1) will serve to show the distribution of the essential parts of the apparatus.

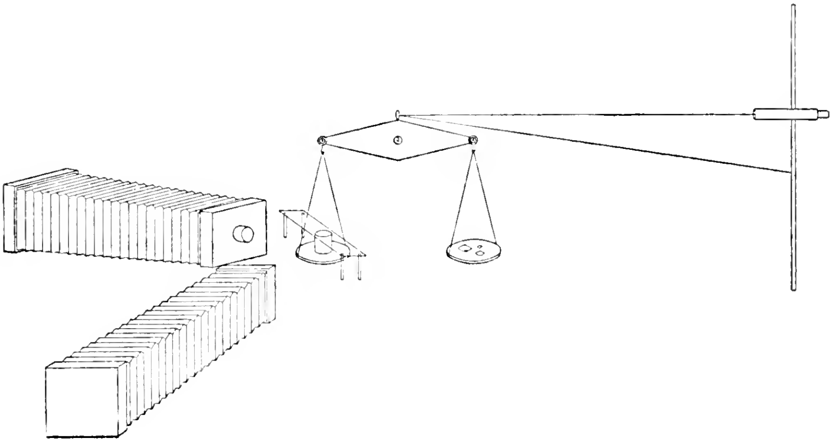


FIG. 1.

Having placed our cylinder in position between 2 clean glass plates, the movable scale pan and the fixed bridge, weights could be added in the other pan of the balance which would serve to compress the cylinder, or in the same pan to exert a tensile stress upon it and the change in length be recorded very accurately by the observer at the telescope. A simultaneous measurement of the diameter was obtained by mounting 2 cameras at right angles to each other and focusing them sharply upon the periphery of the cylinder so as to record 2 perpendicular diameters (Fig. 2). The back of each of these cameras was provided with a permanent slit in front of the plate in such a way that the rotation of the plate behind the slit gave successive images of the same portion of the cylinder to the same scale (magnified about 4 times) upon the same negative.

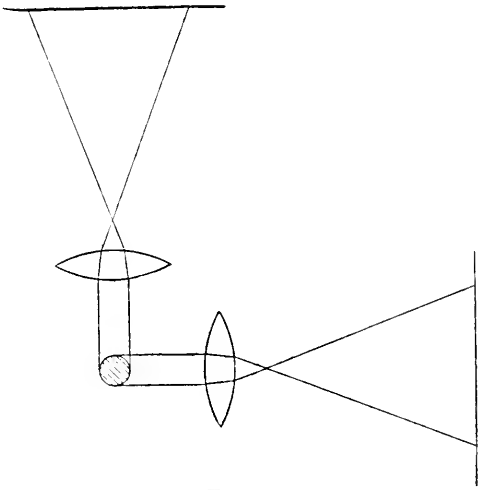
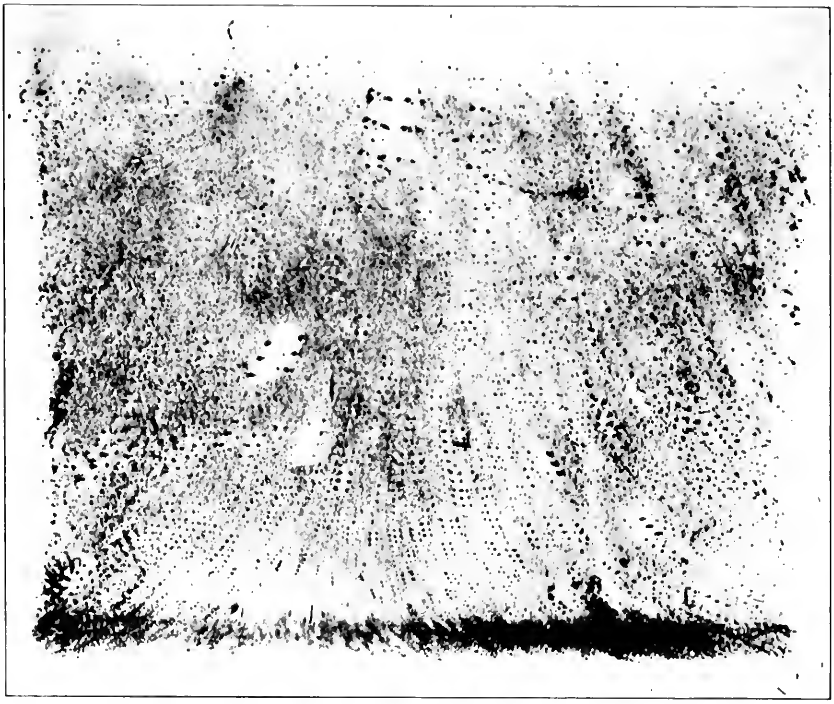


FIG. 2.

The operation was then a simple one, requiring 2 observers: As soon as the foam cylinder had been deposited upon the pan, the bridge placed over it and the balance had reached its position of rest, simultaneous photographs were made with the 2 cameras, and at the same moment a reading of the length with the telescope and scale. A small weight was then quickly added in the other pan. This produced a slight compression, the pan came to rest almost immediately, whereupon a second reading of the telescope and scale was made and a second pair of photo-



Composite photograph showing path of each component particle of a foam cylinder.

graphs taken with the cameras. This operation occupied perhaps 20 seconds, after which a second increment of weight could be added and the proceeding repeated. It was thus possible to make perhaps 6 measurements upon each solid within a period of 2 minutes, during which the foam showed no deterioration whatever.[1] Experiments on Poisson's ratio were also made by compressing cylinders of foam between a fixed plate and a movable plate attached to a micrometer scale, the results being recorded photographically.

The photographs were made with the help of 2 powerful arc lights equipped with reflectors and the most rapidly moving shutters we could obtain ready made. The photographic exposure therefore occupied perhaps a 1/100 of a second.

The remainder of the process was mechanical. The plates were developed and measured with great accuracy upon a comparator, the mean of 5 measured diameters constituting the diameter which was used in each calculation.

It will be seen by a glance at the accompanying table that the results of these measurements afforded a greater accuracy than is usually obtained upon the common solids of laboratory practice, with which no more than 1 per cent. of displacement can be attained.

It was also possible to make a series of photographs of the entire foam cylinder after successive increments of compression and then by superposing the plates to obtain accurate traces of the path of each component particle (bubble). A "composite" photograph of this character is reproduced in Pl. XIV.

It was found that the lines of flow were parabolic ($xy^n =$ const.), as they should be in a solid, according to theory, which is not well illustrated by most experiments.

It was also found that such masses of foam could be ruptured, and that in this respect they behave sensibly like very rigid solids, such as steel, cast-iron, or rock, in spite of the fact that

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[1] The apparatus here described was obviously intended to furnish data for a complete discussion of the elastic constants of the pseudosolid, including the relation between force and displacement, but the lack of a stable pier in our laboratory made it impossible to carry out the latter measurements and was the immediate cause of the suspension of the work until more favorable conditions should be available.

TABLE.

Photograph No.	Length, y.	Width, x.	Poisson's Ratio.			$\sigma = .500 +$	$\sigma' = \sigma'' +$
			σ	σ'	σ''		
Compression.							
24–1	18.952	16.210	—	—	—	—	—
–2	18.827	16.268	0.542	0.542	0.502	+0.042	+0.040
–3	10.702	16.316	.490	.496	.505	— .010	— .009
–4	18.577	16.369	.489	.496	.507	— .011	— .011
25–2	18.452	16.429	.502	.512	.510	+ .002	+ .002
–3	18.327	16.482	.497	.509	.512	— .003	— .003
–4	18.202	16.529	.482	.497	.515	— .018	— .018
Compression.							
22–1	20.577	16.328	—	—	—	—	—
–2	20.327	16.420	0.459	0.464	0.504	—0.041	—0.040
–3	20.077	16.523	.483	.491	.509	— .017	— .018
–4	19.827	16.614	.468	.481	.514	— .032	— .033
23–2	19.577	16.717	.473	.490	.519	— .027	— .029
–3	19.327	16.821	.474	.497	.524	— .026	— .027
–4	19.077	16.936	.483	.511	.529	— .017	— .018
Compression.							
30–1	20.577	16.016	—	—	—	—	—
–2	20.077	16.217	0.507	0.516	0.509	+0.007	+0.007
–3	19.577	16.418	.498	.516	.519	— .002	— .003
–4	19.077	16.630	.497	.526	.529	— .003	— .003
31–2	18.577	16.847	.495	.534	.539	— .005	— .005
–3	18.077	17.065	.490	.539	.550	— .010	— .011
–4	17.577	17.311	.493	.555	.561	— .007	— .006
Tension.							
28–1	18.077	15.760	—	—	—	—	—
–2	18.577	15.553	0.484	0.475	0.490	—0.016	—0.015
–3	19.077	15.363	.474	.455	.481	— .026	— .026
–4	19.577	15.143	.501	.472	.471	+ .001	+ .001
29–2	20.077	14.962	.495	.458	.462	— .005	— .004
–3	20.577	14.756	.509	.461	.454	+ .009	+ .007
–4	21.077	14.598	.499	.444	.446	— .001	— .002

The values of Poisson's ratio are computed from the 3 equations,

$$\sigma = \frac{\log x_0 - \log x}{\log y - \log y_0}$$

$$\sigma' = \frac{\Delta x}{x_0} \cdot \frac{y_0}{\Delta y}$$

$$\sigma'' = \frac{y_0}{\Delta y}\left(1 - \sqrt{\frac{y}{y_0 + \Delta y}}\right).$$

The equation for σ results from the assumption that the loadstrain relation is an exponential.[1] σ' is the ratio of the observed lateral contraction to the linear elongation expressed in terms of the initial dimensions; and σ'' is the same ratio, the lateral contraction being computed on the assumption that the volume remains constant.[2]

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[1] Amer. Journ. Sci., Nov., 1893, p. 348.

[2] Stewart & Gee, General Physics, p. 194.

the absolute value of the modulus of rigidity of the foam is extremely small. The ruptures took place at rather more than 45° to the direction of the compressive force, and in symmetrical cases 4 systems of fissures were developed in 2 planes at right angles to each other, as has been found by Mr. Adams in his experiments on marble, as well as by many earlier observers.

According to a theory of elasticity published by one of us in 1893, the continuity of a solid under linear compression should be represented by the simple formula $xy^\sigma =$ constant, and the attempt was made to determine the value of σ for this foam, with the result that σ was found nearly or quite indistinguishable from one half. σ in this equation represents Poisson's ratio, which, according to the molecular theory adopted by Cauchy and himself, should in all cases be exactly one-fourth. On the other hand, for a theoretically incompressible solid, Poisson's ratio is necessarily one-half. Now, the mass of foam experimented upon is certainly highly compressible, or in other words, its bulk modulus is small, but the results of the experiments showed that the modulus of rigidity is very much smaller than even the modulus of compressibility, so that σ is nearly $\frac{1}{2}$.[1]

Further experiments on this pseudosolid have been necessarily postponed, but even the results which have been obtained

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[1] Poisson's ratio is ordinarily defined as the ratio of lateral contraction to axial elongation. This definition should, however, be limited to the case of infinitesimal strain. This may be shown by considering the case of an incompressible mass of unit volume, when the equation of continuity must evidently be $x^2y = 1$ or $xy^{1/2} = 1$. For infinitesimal strain in this case we have

$$\sigma = -\frac{dx}{x} \Big/ \frac{dy}{y} = \frac{1}{2}$$

while if the common definition is extended to finite deformation we should have

$$\sigma = \frac{1 - x}{y - 1} = \frac{x^2}{1 + x}$$

which becomes $\frac{1}{2}$ when x differs infinitesimally from unity but is in general a variable. The theory of finite strain referred to in the text may be derived from the hypothesis that

$$\frac{dx}{x} \Big/ \frac{dy}{y}$$

is constant, or that

$$\sigma = \frac{\log x_0 - \log x}{\log y - \log y_0}.$$

appear to lead to some interesting reflections. They certainly offer a confirmation from a new standpoint of Thomson's theory of solids for which so much other and more exact evidence is accumulating, and in so far as the foam is comparable with a true solid, it suggests some new ideas upon the nature of the molecule itself. In the foam, when statical conditions are reached, the molecules (bubbles) themselves are not in motion. From this point of view, the molecule is merely the space enclosed between a fixed set of equipotential surfaces, and what has been regarded as molecular motion is confined to the corpuscles constituting the molecule, instead of being an attribute of the centroid of the molecule itself.

In the foam much is known regarding the form of these equipotential bounding surfaces. Lord Kelvin has shown that the figure of stable equilibrium corresponds very closely to a regular octahedron truncated by a cube in such a way that all the 36 edges of the resulting figure are of equal length. Of the 14 faces, the 6 corresponding to the cube are true planes, whereas the 8 corresponding to the octahedron are slightly curved. The curvature of these faces was found approximately by Lord Kelvin, but the exact expression for these surfaces appears to be as yet unknown.

The assumption of Cauchy and Poisson which has led to so much controversy between the uniconstant and biconstant theories of isotropy, was merely that molecules act as mass points, attracting or repelling from their centroids. This was a very natural assumption, and, as Saint Venant pointed out, is no other than that made by Newton in developing the theory of gravitation, viz., that celestial bodies attract towards their centers. It is also known that some substances, especially glasses, nearly fulfill the conditions expected by Cauchy and Poisson, that is, σ equals nearly $\frac{1}{4}$. On the other hand, the experiments of various physicists, and especially of Voigt, show that, for crystalline substances, the rariconstant theory of elasticity is totally untenable and σ often differs greatly from $\frac{1}{4}$. Now, it seems pertinent to reflect that while from certain points of view the planetary masses may be regarded as mass points, when phenomena such as that of precession and mutation are considered, the planets can no longer be so regarded, their attraction being in reality perpendicular to their spheroidal surfaces. It seems as if similar considerations must apply also to molecules. If a molecule is in fact a space bounded by equipotential surfaces and filled with a swarm of moving corpuscles, the attraction here too must be perpendicular to the equipotential surfaces, and the molecule will be centrobaric only under certain limiting conditions. It thus seems possible to think of an isotropic body as composed of fourteen-sided molecules, not always in their simplest shape but answering to Kelvin's figure after distortion has taken place.

We found it impossible to produce linear compression of prismatic masses of foam without a certain amount of permanent set. Reflecting on the nature of the pseudosolid, it appears fairly certain that the bubbles were not all of one size, in spite of all care which might be applied to making the mass fine-grained and homogeneous. Partly on this account also, the orientation of the several pseudomolecules cannot have been uniform. Now, if such a mass is subjected to a linear compressive stress, it is clear that some pseudomolecules must be almost in a position of labile equilibrium so that even a small amount of distortion must push some of the bubbles into new positions, the edges of some of the tetrakaidekahedral molecules being forced beyond the corresponding edges of their neighbors in such a way that when the pressure was removed they could not spring back into their original positions. Even the mere lack of uniform orientation of the pseudomolecules aside from tending to set up unstable equilibrium would seem seriously to affect the results of the application of force, since the resistance which they offer must differ somewhat according to the direction of the several faces; thus a force applied to the plane cubical faces must produce different results from one applied to the undulating octahedral faces of the pseudomolecule. Consequently, even if there were no difference in size, some of the pseudomolecules would break or be so distorted as to escape from their original positions of equilibrium before others were similarly affected.

Do not these facts throw a certain amount of light on the nature of viscosity and after action? Maxwell's theory of viscosity[1] presupposes that various molecular groups are in different states, so that even a very rigid mass like steel contains a certain proportion of fluid molecular groups. With so heterogeneous a mass as steel, this hypothesis may possibly be valid, and yet it does not appear thinkable that in a single clear crystal of a simple compound such as quartz or mica, a portion of the molecular groups is in reality fluid, as Maxwell supposes, and the remainder solid. It is very well known that a high temperature (about 1800°) must be employed to convert quartz into a glass, or in other words, to fuse it; that well developed quartz crystals deposited from aqueous solutions at temperatures below the boiling point of water could really be in part fluid appears to us extremely improbable. On the other hand, when crystalline masses possess a confused orientation, as in the case of marble or of pure platinum consolidated from a melt, it is at least thinkable that the difference of orientation alone is sufficient to bring about the deformation of some molecules before others have reached their elastic limit and the dislocation of other molecules so oriented as to be ill supported by their neighbors. It is possible that in this way the phenomena of solid viscosity and after action may arise.

It may be worth while to call attention to the fact that Kelvin's fourteen-sided solid suggests the possibility, and perhaps the convenience, of a new resolution of the forces acting upon a cube. The ordinary method of procedure is, of course, to resolve a system of inclined forces acting on a cube into 6 normal and 12 horizontal components. Now if these 12 components are combined three by three, they may be replaced by forces acting perpendicularly to the centers of the octahedral faces: and the phenomena seem to indicate that this is the actual resolution in nature.

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[1] Maxwell supposes a solid to consist of groups of molecules of 2 kinds. Of these, one kind shows relatively great stability and in a true solid is so abundant as to build up a resistant framework. The other kind of group is so unstable as to break up spontaneously or on slight provocation, and if it was exclusively present the medium would be a viscous fluid. Maxwell ascribes the phenomena of *elastiche nachwirkung,* or Kelvin's viscosity of solids, to a mingling of the two sorts of molecular groups. (Constitution of Bodies in Encyclopedia Brittanica.)

On the whole, therefore, this pseudosolid is an extremely suggestive material and deserves the study which we hope in future to give it.

We take pleasure in acknowledging the very efficient assistance which has been afforded us both in the experimental work and in the computation by our associate, Mr. C. E. Van Orstrand; also our obligation to Mr. Norman W. Carkhuff for placing the facilities of the photographic laboratory of the Geological Survey at our disposal.

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THE VITAL FABRIC OF DESCENT.

By O. F. Cook.

INTRODUCTION.

More fundamental than any other problem relating to organisms is the question of the method by which their development has been accomplished. Any progress in this direction places us nearer to an understanding of the real nature and essential conditions of organic existence. To solve the problem, or even to approach a solution, requires a choice to be made among the infinity of biological data which science has already amassed, to say nothing of the still greater multitudes of unrecorded facts which encounter us on every side. Without a choice of clues or a criterion of evidence, our search is unscientific, hopeless wandering, with every probability of failure and no prospect of success.

The history of evolution has furnished, even in its first half-century, ample evidence of the truth of this fact. The first step toward a causal explanation still remains to be taken; indeed, we have not yet decided which way to face in taking it; whether to seek the causes of evolution in the environment or in the organisms themselves. The present paper gives reasons for believing that the chief agency of evolution is to be found in the association of organisms into interbreeding species, and, not in the external conditions, nor in the isolation of individual variations. A species is not a mere aggregation of similar individuals, but a fabric of interwoven lines of descent, and it is only in such associations that evolutionary progress goes forward, or that the vitality of organisms can be permanently maintained.

The standpoint from which these biological relations can be perceived was indicated as far back as 1895, but was first formally presented in 1901.[1] It differs fundamentally from earlier structures in the same field of thought in its conception of the nature of evolutionary motion. Two alternatives had thus far monopolized the interest of the scientific world, and both had proved to be inadequate to accommodate the facts of organic existence, or to conduct us toward more detailed explanations of them.

The progressive development of organisms had been conceived as due (1) to environmental causes, and (2) to determinate internal forces or "hereditary mechanisms." The kinetic theory was the result of contact with facts which showed that both these suppositions were wrong. The true actuating causes of evolution do not lie in the environment. Neither is the forward progress or vital motion of species determinate, or restricted to a particular direction; it has great freedom of choice of environmental opportunities.[2]

The kinetic interpretation accommodates and admits natural and consistent relations between numerous other facts which had appeared to conflict with each other or with the doctrines which had undertaken to explain them. The normal condition of evolutionary progress is found in symbasis, that is, in the traveling together of the members of the specific group. New variations among the individuals of such groups are prepotent and can be preserved, whether useful or not, without being segregated. The environment does not cause the evolutionary variations, but it can induce adaptations by restricting the progressive development of the species to particular directions or characters. Selection is thus a negative factor, instead of a positive or actuating agency of evolutionary motion.

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[1] A Kinetic Theory of Evolution, Science, N. S., 13: 969.

[2] Evolutionary Inferences from the Diplopoda, Proc. Entomological Society of Washington, 5: 14, March, 1902.

In line with the previous teaching, that evolution is due to the environment, it has been held that interbreeding hinders or prevents evolution by interfering with the preservation of new variations; sexuality, in other words, has been reckoned as anti-evolutionary. In complete contrast with this is the kinetic interpretation, that the continued interbreeding of the numerous and diverse individuals of the species is essential to sustained organic progress. Evolution becomes, in short, a sexual process. This distinction is not merely a matter of terms and definitions, but is capable of being tested by application to established facts of evolutionary history.

In accordance with the earlier view, that sexuality was anti-evolutionary, it has been assumed that the complex and specialized bodies of the higher plants and animals are asexual structures whose development has been accomplished by the suppression of sexuality in alternating generations of individuals. A more careful inspection of the facts shows that instead of evolution having been accomplished through alternation of generations, or having been accompanied by a greater and greater accentuation of asexual structures, it has remained closely attached to the sexual process of cell-conjugation, and dependent upon it. The bodies of the higher plants and animals are not built up between conjugations or subsequent to the completion of the conjugation of the parental reproductive cells, as often supposed. The reproductive cells divide and build up the new structure while still in the sexually double or conjugating condition.

This phase of the subject has been treated in a previous publication.[1] The present paper undertakes only a brief and informal presentation of some of the general consequences and applications which flow from the recognition of symbasic interbreeding as the normal condition of organic existence, and of evolutionary progress. By emphasizing and applying the fact that organic descent is a continuous network, it seeks to avoid the danger of mistaking the results of violations of the law of symbasis for examples of genuine, constructive evolution. All

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[1] Cook, O. F., and Swingle, W. T., 1905. Evolution of Cellular Structures. Bulletin 81, Bureau of Plant Industry, U. S. Dept. of Agriculture.

evolution might be described as organic change or motion, but it is not safe to assume the converse, that any and all organic changes represent evolution. Degeneration is quite as general a phenomenon as evolution, and the two are easily confused.

EFFECTS OF SEGREGATION.

Many discussions of evolution rest upon abstract terms which have no concrete meaning or definite application. Such expressions as *prepotency* and *reversion* are veritable stumbling-blocks in the evolutionary theories of those who use the words without taking into account the different relations of the phenomena grouped under them. Having once made the assumption, for example, that mutations are instances of a normal saltatory evolution, it is natural to look upon the prepotency which brings "reversion" as tending to prevent evolutionary progress by "the swamping effects of intercrossing," of which the last decades have heard so much. Segregation appears essential for the preservation of new characters; it becomes, in other words, a primary factor or condition of evolution. This series of deductions leads, however, to a biological absurdity, because extreme segregation or inbreeding not only puts an end to true evolutionary advance, but causes the deterioration of the organisms themselves.

The phenomena which have been interpreted as mutations and reversions can be accommodated under a kinetic theory of evolution without this fatal inconsistency of inference. Instead of affording progressive new characters, or constituting new species, there are reasons for believing that mutations are digressive lapses from normal heredity, induced by inbreeding or too great segregation. The "prepotency of the wild type" which "swamps" these abnormalities is not a backward step along the highway of evolutionary progress. It marks, instead, a return from a too narrow sidepath. The reversion is only formal; it represents a restoration rather than a retrogression.

Evolution has seemed to go backward only because the sidepath has been mistaken for the main thoroughfare. The prepotency which seems to obliterate the mutational "new species" is the same which carries forward the evolutionary progress of the whole specific aggregation of interbreeding individuals. The real and permanent advance is made in the main body of the species, not among the stragglers from the flanks, nor by the distraught captives of our cages, pastures and gardens.

That the plant mutations which "come true to seed" are often extremely uniform or constant, does not make it certain that they are true species, but indicates, rather, the contrary, since prosperous natural species show abundant individual diversity. To give such "sports" formal descriptions and Latin names does not prove that they represent genuine species formed in the normal course of evolution; it simply assumes the identity of two biological conditions essentially distinct.

The possibility that mutations, or even genetic variations, may also be induced by new environmental conditions, as believed by Darwin, is not excluded. But even in such cases the environment would need to be regarded as furnishing the *occasion* of the change, rather than as being the true, actuating *cause*. Very diverse mutations, of the coffee plant, for example, have been found to arise under the same environment, and closely similar mutations under very different environments.

The changes by which many organisms are able to accommodate themselves to different conditions appear to be of little or no direct significance for evolutionary purposes, though the diversity manifested under the different conditions may serve the same physiological purposes as other intraspecific differences in connection with symbasic interbreeding. Evolution is an integration of genetic variations, not of environmental influences.

Segregation, or isolation, conduces to the formation of new species by the subdivision of older groups, but it is not on that account to be reckoned as a cause of evolution. Free interbreeding throughout the range of a species tends to keep the characters uniform, but it does not tend to keep them stationary. The characters remain relatively uniform because interbreeding holds the members of the group well together on their evolutionary pathway, not because progress is prevented by interbreeding. Free interbreeding "swamps the incipient lines of variation" only when the change is of a degenerative nature, and not truly symbasic and constructive.

If the two geographical halves of a species become separated they will also become different, but this only shows that evolutionary motion is everywhere taking place; it does not prove that either of the new species has travelled farther than the undivided group would have gone, or that segregation has served as an agency of evolution. Evolution has very little to do with the origination or subdivision of species; this is almost entirely a matter of segregation, geographical or otherwise, and is a mere incident of the process of change. That separated groups of organisms so universally and so promptly become different, affords the strongest possible testimony that evolutionary motion is not determinate or limited to one direction, but it gives no warrant for looking upon isolation as contributing to evolutionary progress.

As general evolutionary factors, natural selection and geographical isolation are negative and restrictive; they influence, but do not actuate, the progress of species.

To say that isolation causes species-formation because it brings the separated groups under different environmental or selective conditions is only to confuse the issue. Segregated groups become different, even in the same environment, and in characters having no relation to environmental differences which may exist. Unsegregated groups can remain relatively uniform in very different environments. No evidence has been found that any action of the environment can produce evolution, either by direct transformation or by the indirect influence of selection and segregation. All nature abounds, on the other hand, with evidence that evolution can take place without environmental differences, without selection, without isolation. Evolution takes place without any external cause or compulsion, and is capable of no explanation which does not recognize the fact that specific groups or organisms, no less than sidereal systems, are in motion.

ORGANIC DESCENT A CONTINUOUS NETWORK.

The normal individual diversity which has been destroyed by inbreeding is not restored by mutation; possibly it would reappear if the different mutations were propagated in sufficient numbers and allowed to intercross freely: but in domestication they always suffer still further inbreeding.[1] Finally, even crossing ceases to be effective for restoring the normal condition of intergraded individual diversity. Hybrids of inbred mutations often follow closely the parental lines, and soon separate again into the distinct types, as discovered by Mendel. It is hoped by some to recombine these fag-ends of undone creation into " new species," but this is to see Persian rugs in rag carpets, or oil paintings in three-color prints.

A general misconception of the nature of evolutionary motion has arisen because attention has been directed so largely to domesticated species, in which descent has been limited to single or very narrow lines. Phenomena of degeneration induced by inbreeding have been interpreted very often as results of changed environmental conditions. The mistake has been made of supposing that evolutionary progress is a mere resultant of external influences, whereas it is in reality a highly composite motion carried forward in the intricate network of descent of the normally interbreeding species. Natural selection forbids the weaving of patterns discordant with the environment, but no external influence actuates the loom. Nor need we allege any other and more hypothetical force or agency as conducting the change, the necessity of which is inherent, not in the individual organisms as such, but in the association of diverse individuals in interbreeding groups or species. If the physical basis of this law of symbasis were understood the general fact of evolution would also be comprehended as a natural and necessary

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[1] The abnormal amplitude of mutational variations has been likened in another place to the unusual fluctuations of temperature in disease. The abnormality is in the conditions; mutations may be of the same essential nature as normal variations, into which they seem to grade as insensibly on the one side as they do into obvious monstrosities on the other. Professor DeVries has explained that he gave *Oenothera lamarckiana* special attention in his search for mutations because it was " rich in monstrosities." DeVries, 1905, A New Conception of the Origin of Species, Harper's Magazine, 110: 212.

consequence. Instead of preventing evolution by "swamping effects" symbasic interbreeding is the true method or principle by which evolution has been accomplished.

Normal descent does not go forward in simple series of uniform individuals; it is a broad network of closely interwoven diversity. Once frayed by inbreeding into narrow, "unit-character" shreds, the vital fabric is hopelessly weakened, and the hereditary pattern distorted. The higher the organisms the more acute the requirement of symbasic interbreeding, and the more prompt and obvious the damage wrought by abnormal segregation. To insist that mutational aberrations are suddenly originated, genuine species, is the same as to assert that the idiot offspring of cousins afford true examples of the steps by which the perfection of the human race has been attained.

Through long-continued selective inbreeding, cultivated plants have been broken up into numerous local varieties of mutative origin. These are frequently quite as distinct from each other, in the purely descriptive, taxonomic sense, as wild species in nature, but their evolutionary status is very different. Wild species in the truly normal and progressive (prostholytic[1]) evolutionary condition have a multifarious, intergraded individual diversity, not to be found in mutative varieties. Species which have not been domesticated too long show the intermediate (hemilytic) condition of retarded evolution. Inbreeding has induced an abnormal uniformity in which the degenerative mutations begin to appear.

Thus the coffee shrub has not yet become a mere congeries of local varieties, but has an astonishing uniformity of type. Seeds brought from remote regions and sown in the same place produce plants of almost indistinguishable likeness. Of very distinct, true-to-seed mutations of coffee, however, there is no longer any lack, but very few of them have been preserved and cultivated, because of their inferior powers of seed production — a very practical proof of their degenerative nature. That adverse conditions or abnormally restricted distribution may bring about in nature evolutionary conditions analogous to those of our domesticated plants, is, of course, to be expected, but

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[1] Stages of Vital Motion. Popular Science Monthly, 63: 14. May, 1903.

very rare and local species are correctly looked upon as remnants verging toward extinction rather than as ascendant newborn types.

Some have thought to reconcile the idea of a progressive evolution with the older notion of constancy of characters among the members of a species by supposing that evolutionary changes proceed by imperceptibly gradual, infinitesimal steps, and must therefore have required millions on millions of years. As a matter of fact, however, differences between the individual members of species in nature are commonly quite perceptible, and often strikingly obvious.

It has been attempted, also, to distinguish between what are called continuous, or gradual, and discontinuous, or saltatory, variations, the former to be found within specific lines, the latter initiating new species. This distinction is artificial and misleading; variations may be discontinuous but they do not disconnect the species. No reason is apparent why a species might not be completely transformed within a few years, decades or centuries through the acceptance, by all of its members, of a new character or characters. Instances where such changes appear to be going on have been adduced by several naturalists. Evolutionary progress can be accomplished in this way much more rapidly than if it were necessary to replace the older form of the species with the progeny of a mutation, which needs to be kept isolated from the older species lest it be swamped by intercrossing. Prepotency, the power to transform the species, instead of being swamped, is the practical difference between genetic variations and mutations.[1]

The kinetic theory sets no limits to the length of the steps, nor to the rapidity with which they may be taken. It implies, however, that the evolutionary progress of the species goes forward as a network of descent, broken neither by sudden transformations nor by periods of stationary constancy. As far as our present perceptions carry us, variations may appear fortuitous. Evolution, however, is not accidental nor casual, but necessary and universal. Neither is it passive nor intermittent, but persistently and continuously conservative and constructive.

[1] The Evolutionary Significance of Species, Smithsonian Report for 1904, p. 397.

WHY MUTATIONS ARE RECESSIVE.

That inbreeding induces many of the evolutionary aberrations of domestic plants and animals is shown by the fact that such characters commonly disappear in crosses with the symbasic, or freely-interbred, wild type. Darwin's classical experiments with pigeons have been repeated and supplemented by many observers in Europe and America, and additional testimony of the same kind has been published recently by Professor Castle.[1] The "Angora coat" and other similar abnormalities of inbred animals are found to be recessive, in the Mendelian sense; that is, the long hair disappears when crossed with the short.

Whether such characters are "recessive" or "dominant," or whether they appear at all, may depend on the relative degrees of inbreeding, rather than upon any special strength or weakness of characters as such. Like normal genetic variations, mutations are prepotent with their own equally inbred relatives, but abnormalities induced by inbreeding can be corrected when more remote lines of descent are brought together. Professor Castle maintains that to preserve such mutations as the long-haired guinea-pigs and horses they must be bred with others of like kinds, but in accordance with the present interpretation it will be found more effective to continue inbreeding with their own immediate, unmutated relatives. The fact that these long-haired mutations arise in the first place from short-haired parents, should not be overlooked.

Plant mutations which can be propagated asexually or by self-fertilization are often remarkably constant. With animals the experiment is more difficult because some crossing, at least of individuals, is necessary to reproduction. The remote chance that mutations sometimes initiate new species would be still further attenuated if it were necessary that two of the same kind arise at the same time and place in order to make possible the preservation of the new type.

Under the kinetic theory[2] no fundamental importance is

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[1] The Heredity of "Angora" Coat in Mammals, Science, N. S., 18: 760, 1903.

[2] A Kinetic Theory of Evolution, Science, N. S., 13: 969, June 21, 1901.

ascribed to mutations. The fact that one member of a group of inbred individuals has mutated, is accepted as an excellent reason for believing that others are ready for the same step, thus explaining at once the relative prepotency of a mutation under continued inbreeding, and its "reversion" in the presence of the wild stock or of a more symbasic breed. On the other hand, the crossing of two mutations of distinct ancestry, even though of closely similar form, constitutes a decrease of inbreeding, and carries with it a possibility of restoration to the normal type. Darwin found that crosses of unrelated white pigeons "reverted" to the blue plumage of the wild type, but he did not hold that such precarious, pathological variations are factors in the evolution of species in nature. Symptoms of disease have often helped, however, to understandings of healthy functions.

Mutations are abnormal manifestations of the normal phenomenon of variation or diversity inside the species. The prepotency of mutations when bred with their own inbred relatives corresponds to the prepotency of normal variations. The "reversion" or negative prepotency of a mutation in the presence of a more widely symbasic stock does not prove that new species originate in nature by the segregation of mutations; it simply increases the improbability of a general theory of evolution built on the narrow basis of the mutations of domesticated plants and animals.

The rejection of the hypothesis of the origin of species through mutation does not make it necessary to disregard any of the facts which have been collected to support it. The objection is not to the data, but to the generalization, and to the use of a standpoint which can be maintained only while other equally pertinent facts are disregarded.

In his report of experiments on "Color Inheritance in Mice"[1] Professor Davenport notes that albino mice of mixed parentage were found to be more prepotent, or less completely recessive than those of pure descent. Instead of more gray progeny as an inheritance from the gray parent, they gave a larger proportion of white offspring, a result as directly in accord with the kinetic theory as it is at variance with the current mechanical

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[1] Science, N. S., 19: 110, January 15, 1904.

explanations of Mendel's laws. White mice are now an inbred domesticated variety while the gray mice with which they are compared have had much more recent opportunities of interbreeding. Recessive gray mice can doubtless be secured by inbreeding, and dominant white mice by interbreeding.

That mutations like those which "Mendelize" as "pure recessives" should be able to "revert" after many generations, to a parental type by crossing with each other, would also seem to show that the whole question is one of ancestry and methods of descent, rather than of pure germ cells, chromosomes, or character units. Such explanations of Mendelism can only show in higher relief the abnormality of the phenomenon, instead of justifying themselves as general "principles of heredity."

In the higher plants and animals the conjugation of the parental nuclear elements is not completed until the fusion of chromatin, or mitapsis, has occurred, before the so-called "reducing-division" which precedes the formation of the germ-cells for the next generation. Inability to form normal germ-cells may explain why the line of descent is broken at the stage of sexual reproduction, in sterile mutations and hybrids, though in other cases equally fatal derangements may appear, either before or after the reproductive period. The failure of the chromosomes of sterile hybrids to behave normally is no proof of the existence of a predetermining "hereditary mechanism"; it is but one of the many related phenomena which show that the evolutionary mischances of hybrids and mutations are not confined to the external form, but may affect any part of the organism, and even the cells of which the body is composed.

MUTATION AND REVERSION.

Evolutionary debility and derangement through inbreeding are old and well-known facts, but, notwithstanding the frequent use of the term, it has yet to be shown that there is any such phenomenon in nature as reversion, in the strict sense — any actual doubling back upon the evolutionary road. There is sometimes an arrest of development; accidents or unfavorable circumstances may keep a plant or animal from attaining the normal stature or form of its species, and thus leave it with a suggestion of a more primitive or ancestral type. A variety narrowly selected in one country to secure the accentuation of its peculiar characters, may deteriorate, or fail to reach the same degree of specialization when the cultural conditions of growth are changed. Through degeneration, or loss of complexity, a species may appear more primitive or less evolved than it really is. To reversion is also ascribed the occasional cropping-out in the individual of some ancestral peculiarity (atavism), but these minor fluctuations of form minister to the healthful diversity of the species, and are far from proving that evolution has turned backward. The transformation of pistils and stamens into petals, as in the formation of double flowers and similar mutative changes, is not, as sometimes supposed, a reversal of evolutionary processes, but is in the direction of developmental history — an over-shooting of the mark, as it were. Reversion would change petals back to stamens; this seldom happens, and when it does we recognize it as a recovery of normal form and function. It is now coming to be appreciated that the evolutionary history of the higher plants has involved a progressive sterilization and vegetative specialization of parts which were once devoted to reproductive purposes. Even the cells of which the bodies of the higher organisms are composed are sexual in their origin and represent a condition of prolonged conjugation.

The final inconsistency in terms is reached by those who have suggested reversion as the cause of the same phenomena which it is held to obliterate, that is, the mutations themselves. This is to use the one word reversion in two directly opposite senses.

Mutations often suggest other species of the genus, as in *Coffea*, and have been termed "reversions" to an ancestral character;[1] but just such "reversions" are said, also, to "re-

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[1] The "Maragogipe" mutation of *Coffea arabica*, for example, has a superficial resemblance to *Coffea liberica*, and has been held by some to be a cross between the two. Other mutations of coffee originating in Central America share features of several of the wild African species.

Mr. Luther Burbank has found that hybrids also are sometimes more obviously similar to other members of the genus than to their own parents. Thus the Wickson plum, a hybrid between Japanese varieties of *Prunus triflora*, was believed by Professor L. H. Bailey to be descended from *P. simoni*, a Chinese vert" to the normal type of their own species, through intercrossing. It may be admitted, perhaps, that a mutation is as near as anything to the original idea of reversion; it is at least a *di*version, an evolutionary aberration, or wandering aside. But in this sense reversion becomes synonymous with mutation, and is thus a superfluous term, as well as inappropriate. It is equally at variance with the current meaning of the word to refer to the recovery of the normal form of the species as reversion, since this process is conservative and reconstructive rather than degenerative or retrogressive, however much an "improved" breed may appear to "deteriorate" when crossed with its wild or less inbred relatives. If this be reversion the word should be relieved of all sinister implications, at least in evolutionary usage.

Better than the substitution of a new term for "reversion" would be the transfer of emphasis from this negative concept to the kinetic view of prepotency, not in the Mendelian sense of an arbitrary and inexplicable "dominance" of one character over another, but mindful of the law of proportion between symbasis and prepotency, without which the facts of descent are a hopeless tangle of apparent contradictions. *The prepotency of a variation depends upon the extent of the normal interbreeding under which it arises.* The law of mutation is the biological converse: *As the lines of descent are narrowed the amplitude of variations increases and reproductive fertility declines.*

PREPOTENCY ILLUSTRATED BY PARALLEL VARIATION.

The abnormality of mutations is scarcely to be appreciated without a recognition of the normal diversity (heterism) of the

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species which had not been introduced into the United States at the time when the cross was made.

The same phenomenon occurs among human hybrids. Mulattos are sometimes very black, and sometimes white. Wallace observed in the Portuguese settlements of the Malay Archipelago that the mixed population has "become darker in color than either of the parent stocks," and in Brazil that crosses between Portuguese and Indians are "not infrequently lighter than either parent." (The Malay Archipelago, p. 257.)

"Another clear fact is the rapid loss of resemblance of the offspring to the Indian parent, the white element always predominating; the aboriginal seems to be merged into the Spanish in two generations." (Orton, The Andes and Amazon, 3d Edition, 465.)

members of the same species. Mutation is a reaction from the abnormal uniformity which is the first effect of selective inbreeding. Not only do the same or closely similar mutations occur repeatedly in the same species, but different species and genera may mutate in the same way, just as the same disease may call forth similar symptoms in different plants or animals. But even in this respect mutations may be looked upon as furnishing indications of the behavior of normal variations. Species, like other bodies, can move only from where they are; each "new character" is, after all, only a modification of parts already existing. The novelty is very largely that of the language in which it is described. Genetic variation is not completely indeterminate, fortuitous or in all directions at random; nor is it narrowly determinate or limited to one character, or two characters, or to any small number of characters, as we well know from the excellent example of individual diversity afforded by the members of our own species. Variation does of necessity have reference to characters already existing, and must be consistent with these if the change is to be advantageous. Some varietal or racial characters are also prepotent over others, and with sufficient opportunity of interbreeding will continue to spread, and to become more and more accentuated.

It is therefore in accordance with the most obvious probabilities of kinetic evolution that nature should abound in instances of parallel development.[1] The same or similar variations are likely to arise more than once and to have a similar welcome or rejection by characters already existing. Tendencies of variation once begun in a species are continued, even after the species subdivides. Each natural group, of whatever rank, was once a single interbreeding species, and every such group represents, in evolutionary history, the subdivision of an original species. Each character or tendency can continue its development, though in the company of different later variations in each of the groups, as they have successively segregated. The static theories, which ascribed evolution to environment, might

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[1] Instances of parallel development have been reviewed recently by Professor Osborn as affording "evidence of a predisposition to similar evolution." (Science, N. S., 21 : 28, January 6, 1905.)

appear to explain parallel variation under parallel conditions, but the recognition of the kinetic principle enables us to understand parallel variation even under different conditions.

Inside specific lines descent is a completely connected fabric, but superspecific descent, the phylogeny of genera, families, and orders, is not reticular at all. For lack of adequate evidence we may be unable to decide which is the nearest relative of a given group, but when we represent our groups as having complex interrelationships we are merely making graphic representations of alternative solutions of unsolved problems. The common possession of an ancestral character affords, in itself, no assurance of closer relationship, nor do the separate acquisitions of similar characters. Each character must be placed, as it were, in its true chronological position before its phylogenetic significance can be appreciated. Without careful regard for sequences, phylogeny becomes as hopeless as history without dates.

If the parallelism of variation be accentuated by selective influences there occur wonderful approximations in the characters of different and unrelated organisms living under diverse natural conditions in remote and isolated regions. The facts have been effectively summarized by Professor Osborn and made the basis of what is called "The Law of Adaptive Radiation."[1] In each continental area and geological period there have arisen among the mammals specialized groups adapted by their teeth to all the different kinds of food available. There are always some with slender skeletons and long legs adapted to escape by running, and others stout-footed and heavy-limbed, able, in all probability, to protect themselves by sheer strength and ferocity or by defensive armor.

Adaptive radiation is inconsistent with both of the current ideas, that evolution is caused by the environment or by a predetermining hereditary mechanism. The conditions are too diverse *to cause* such similarity of results, but at the same time the results are too diverse to warrant the inference of predetermination. The truth lies, obviously, between the two extremes. The environment does not cause evolution, but neither is evolu-

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[1] American Naturalist, 36: 353, 1902.

tion independent of the environment. Evolution must produce characters which the environment can admit, and with unspecialized mammalian types as a beginning, the requirements become similar, even though the regions be different.

With mammals the selective factors are at the very highest, and by competing with and preying upon each other they make by far the most effective part of their own environment. The struggle for existence is a stern reality, and the issue rests, very often, on a narrow margin of speed, strength, armament, or endurance. It need not surprise us, then, that the numerous geological and geographical experiments enumerated by Professor Osborn have turned out so much the same. Kinetic evolution explains the power of radiation, and the selective conditions explain the adaptive results, the extent of adaptation being proportional to the thoroughness of the selection, providing of course, that the group be not narrowed to the point of degeneration. The most specialized types have ever been the most liable to extinction.

INADEQUATE MECHANICAL CONCEPTIONS OF HEREDITY.

The prepotency of symbasic wild types and the "reversion" of domesticated varieties when selective inbreeding is relaxed, are manifestations of the biological laws of which mutation and Mendelism represent the violations. The problems are historical rather than mechanical; to interpret the facts in terms of descent rather than in those of crudely inadequate and wholly hypothetical "hereditary mechanisms." The organism may be described, for some purposes, as a machine, but it is no mere corn-sheller or steam engine, and there is no assurance that we have, as yet, even a basis of conjecture regarding the principles on which it is constructed, or the ultimate nature of the materials of which it is made. What the mechanism does, however, is a very practical and pressing question which need not be postponed on account of any lack of agreement in general theories, if, indeed, the workings of the device do not afford the best clue to an understanding of its structure.

The formal recognition of gravitation and other natural laws or properties has proved useful, although mechanical explanations are still lacking. The principles of evolution are being sought in rare and exceptional phenomena while the apples continue to fall unregarded. Many evolutionary experiments have been proposed which would require extensive and costly facilities to be maintained for very long periods of time. Such suggestions may not be carried out, but they have a present interest as showing that current theories of descent do not apply in nature at large, where the evolutionary possibilities of organisms have been tested continuously for millions of years, and the results are open freely for our inspection.

The question turns on general biological interpretations and standpoints far more than on formal proofs and demonstrations, either syllogistic or statistical. The history of biology shows what diverse and contradictory theories can be proved, or at least rendered plausible, if their authors are allowed to select the facts to go with them.

A general law of organic succession must accommodate all the pertinent facts. Each biologist can test it with the data of his own experience if he have imagination enough to assume, for the time being, the required standpoint. Indeed, one might formulate procedure in such matters by saying that the more general the law the less susceptible it is of being established by reference to any small group of facts. Such reasoning from circumscribed data has always to be bolstered up by the argument, expressed or implied, that the facts must mean what is alleged because they cannot mean anything else, a formula which transmutes our ignorance into knowledge, by sheer intellectual alchemy. We unconsciously admit the author's unconscious assumption that his standpoint is correct and final, and instead of testing it by our own facts we accept his at their face value, though every one of them may beg the question it is supposed to answer.

As long as experiments are limited to conditions of inbreeding by which the desired phenomena can be induced, there will be no lack of evidence for mutations and Mendelism. But even if all the animals and plants were successively domesticated, inbred and conventionalized into "character units," we would still be as far as ever from having ascertained that these are the means by which the constructive evolution of nature has gone forward.

There can be no certainty that any particular species may not, at some remote period and place, be crowded into a narrow corner of the environment, and made to yield degenerative mutations, but this possibility should not cause us to forget that the broad fabrics of continuous, diverse, and gradually changing descent are being woven in the living looms of all the widespread species in nature. To say with Professor Haeckel and others that the abnormal is the important for evolution, is not merely to frame a paradox, it is to confess what in theological language would be termed a most pernicious heresy. For do not isolation and inbreeding represent the very principle and essence of biological evil, the ever-present danger of deterioration, which nature is taking such infinite pains to escape, by all the devices of sex and symbasis? All new characters must, indeed, be classed as abnormal if we think of species as normally constant and stationary, but to base evolution on the degenerate abnormalities of inbreeding darkens counsel indeed.

The acceptance of the laws of planetary motion was impeded by mediæval theology, but thought is now clouded by the opposite tendency, an equally unscientific fear to admit the reality of phenomena not immediately explainable in current terms of physics and chemistry.[1] The facts of vital motion are obscured by mechanical dogmas, vastly complicated, and yet wholly incompetent. In terms of physics and chemistry, we do not know *why* cousins may not marry, *why* inbreeding is destructive, or *why* symbasis is necessary to maintain organic strength and evolutionary progress; but we may be certain that evolutionary doctrines which disregard such primary facts of descent are fatally defective.

Current theories require that new characters be saved by segregation, but organisms are not like chemical compounds, to be preserved by keeping them from contact with others. Protoplasmic compounds are noted, it is true, for their extreme lability or tendency to decompose as soon as life is extinct, but this fact, instead of proving that vital processes are due to the

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[1] Evolution and Physics, Science, N. S., 20: 87, July 15, 1904.

mechanical "forces" hitherto recognized, only shows in higher relief their hyperphysical stability.

The atomic theory of matter has led Professor DeVries and others to assume that morphological alterations are "incumbent on slight chemical changes of the representative particles of the hereditary qualities."[1] We know, however, that organic structures and vital processes persist through a wide range of physical conditions, and in spite of changes of the material particles, or even of the chemical substances of which the living tissues are composed. There is a stability of motion as well as of rest; new characters can be preserved by prepotency better than by segregation.

The higher we go in the scale of organic existence the more obvious these facts become. To keep alive the bodies of the higher animals there must be a constant supply of new materials, and a removal of the fatigue-products of the high-grade vital activity. The animals were able to out-strip the plants largely because they developed superior facilities for secretion and excretion. They are able to make use of a much greater variety and complexity of compounds and can also rid themselves of waste products with more freedom. Plants are able, for the most part, to excrete only gaseous compounds; other rejectamenta have to be accommodated inside the cells or laid down in the cell walls.

The idea that the cellular bodies of plants and animals are built up on simple principles of "developmental mechanics" sees no significance in the wonderful series of gradually superposed complexities which have attended the advance of organisms to their present stages of perfection. To build up our bodies, cells have become associated in immense numbers and highly specialized in form, structure and function. The number and complexity of chemical substances has likewise increased from the simple inorganic compounds used by the soil bacteria to those supplied by the mixed diet of civilized man.

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[1] Professor DeVries also explains in a preceding paragraph: "Chemical substances are changed into others by definite and measurable steps, and hence it seems to me that this rule might prevail for the minutest material particles which determine the hereditary qualities of organisms." (Harper's Magazine, 110:210, January, 1905.)

Reproductive cytological processes have advanced from the brief fusions and prompt redivisions of simple and equal cells to intricate combinations which may not require renewal for decades and centuries. The Sequoias of California and Dracænas of the Canary Islands live as individual trees for thousands of years, and some of our cultivated plants have been grown from cuttings since the earliest dawn of primitive agriculture, behind all human history and tradition.[1]

Still other avenues of vital motion and achievement are to be seen in the complexity of individuals, sexes and polymorphic forms which the higher plants and animals often maintain inside the same species, and in the multitudinous reproductive devices and instincts for weaving this diversity into the still more intricate fabric of descent; a social evolution, in short, which is at once the basis and the prophecy of the still higher intellectual and personal development of man himself.

SUMMARY OF KINETIC INTERPRETATION.

The causes of evolution are still unknown, but we have arrived at the perception that evolution has a very practical physiological function which explains the general fact of progressive change. Organisms are under the necessity of motion; it is the only way that they can maintain their stability and continue to exist. Instead of being moved by environmental causes from a condition of normal constancy of characters, they are, by their very constitution, wheeled against the environment, seeking new avenues along which motion can be made. Nor are their impulses toward diversity and evolutionary progress limited to the environmental side. Species of common origin and inhabiting the same region are found, very often, to have become different in many ways, internal as well as external, which can have no direct reference to the environment.

Instead of having been built upon any general rules or principles of nutrition or tissue-formation, we find in different natural groups the utmost diversity in the solutions of the same bionomic problems, each a testimony of the protean constructive powers of life and of the futility of physiological generalizations based on single species or a few related types.

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[1] The Food Plants of Ancient America, Smithsonian Report, 1903, 481–497.

The more specialized groups abound in characters which instead of being explainable as called forth by natural selection, and hence as useful, appear to have been pushed to worse than useless extremes. It is as though species were impelled from within by an essential *kinesis* or property of motion to make trial of every feasible degree of expression of every attainable character. Kinesis is not a mysterious force or mechanism to be sought in reproductive cells; it is a general property of organisms, as gravitation is of matter. And of kinesis we know more than of gravitation. Two factors and two results are already obvious. The factors are heterism, or intraspecific diversity, and symbasis, or interbreeding in a specific network of descent. The results are the sustained variety of the interbreeding organisms, and the continuous progressive modification of the specific groups.

The normal evolutionary progress or vital motion of organisms is symbasic; they advance in large groups of interbreeding individuals, commonly called species. Separate mechanical explanations of each example of this law are as superfluous as the mediæval angels who pushed the planets round and hurled the meteors. Nobody doubted that the meteors and planets moved, but special causes continued to be conjectured until it was discovered that the earth itself was also in motion. If species were normally stationary, the environment must needs have impelled them. They have, however, motions of their own.

Natural selection neither originates species nor actuates their further development; progressive change would go on whether selection were active or not, and whether the environment were uniform or not. Nevertheless, selection conduces to adaptation, since by permitting changes in some directions and forbidding them in others, it deflects the specific motion. The workings of natural selection are adequately explained only under the kinetic theory, which recognizes the physiological value of organic changes as such, and which thus supplies the materials on which selection can act.[1]

The organic structure is held together and supported by the symbasic interweaving of different lines of descent. When the

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[1] Natural Selection in Kinetic Evolution, Science, N. S., 19: 594.

vital fabric is weakened by narrow segregation or selective inbreeding, mutative degenerations and Mendelian disjunctions appear. Variations thus induced afford examples of evolutionary motion, but in its aberrant and destructive form. Symbasic evolution is a process of constructive integration; it proceeds the better when the diverse individuals of a species remain together, not when they are kept apart. Variations of positive evolutionary significance are prepotent; they strengthen the organism, and are shared and preserved by the vigorous, interbreeding members of the species. The conditions under which a species enjoys its greatest numerical prosperity are also the most favorable for its evolutionary progress.

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THE FOLIACEOUS AND FRUTICOSE LICHENS OF THE SANTA CRUZ PENINSULA, CALIFORNIA.

BY ALBERT W. C. T. HERRE, A.M.

THE following paper embodies some of the results of a study of the lichens of the Santa Cruz peninsula, carried on during the past three years. Only the foliaceous and fruticose lichens are treated at present, the crustaceous lichens being reserved for a later and more comprehensive paper.

As a matter of fact a scientific treatment should take no cognizance of the old arbitrary divisions into fruticose, foliaceous and crustaceous lichens, as they possess no significance and members of one grouping merge gradually into another, all forms being found in one family or even in one genus. In a later paper the author hopes to present the chemical reactions, spore measurements, and synonymy of all the lichens of the Santa Cruz peninsula. The forms selected for treatment in the present paper are mainly those which attract the attention of the general botanist or amateur.

The descriptions and keys have been written from a first-hand study of material collected within the territory described below, and accordingly may not apply in some cases to specimens of the same species from other localities, or agree with Tuckerman's descriptions.

So far as possible, technicalities have been avoided and simplicity, rather than brevity, has been the aim. In constructing the keys an effort has been made to utilize those characters most prominent in the field; a more correct way would be to use the natural characters and classification, rather than the artificial plan followed. The author believes that it is possible to make the study of lichens as easy as that of the Liverworts, Grasses, Compositæ, or other more difficult groups.

The Santa Cruz peninsula comprises that region lying west of San Francisco Bay and the broad, originally treeless Santa Clara valley, and north of Monterey Bay, and forms a natural biological region. In it are included the counties of San Francisco, San Mateo, Santa Cruz and a part of Santa Clara. It rises from sea level on three sides to 3788 feet on Loma Prieta, the highest of the Santa Cruz mountains. The Pacific side of the peninsula is very moist and in the fog-laden air of the redwood or forest formation certain forms of lichens reach a development perhaps unsurpassed elsewhere.

In studying the lichens of this region special attention has been paid to their distribution as it is believed that the presence or absence of lichens is an ecological factor of quite as much moment as the presence or absence of any other plants. To say that lichens are irresponsive to conditions of temperature, light, and moisture, and that they are of no importance in studying plant ecology, is a gross fallacy.

Not all the Santa Cruz peninsula has been explored for lichens, but practically every portion has been visited except the region of the Big Basin. It is believed that the plants described in this paper include a large majority of the forms which are indigenous to this region.

It is now nearly forty years since Bolander collected about San Francisco. His lichens were determined by Tuckerman, a great many being described then for the first time. Since Bolander ceased his work, Dr. Marshall A. Howe collected three or four forms in San Mateo county, which were distributed in the published exsiccata of Cummings, Seymour, and Williams. C. F. Baker also collected a score or less of the commonest lichens about Stanford University, the determinations being made by Dr. H. E. Hasse.

Aside from these no collecting has been done in this region, and there is no doubt tnat careful search will reveal many new forms. Already several new lichens have been found by the author although the crustaceous lichens have hardly been noticed or collected.

The systematic treatment of lichens by Dr. Alexander Zahlbruckner in Die Natürlichen Pflanzenfamilien is as yet only partially completed, but as far as possible this authority has been followed in generic names. Genera not treated in the portion thus far published are defined according to Tuckerman except that the genus *Gyrophora* has been used to designate our forms belonging to Tuckerman's genus *Umbilicaria*.

As far as possible the author has attempted to retain the earliest specific name though he is aware that his attempt has probably not been wholly successful. The synonymy of lichens seems to be in a chaotic condition and is in urgent need of thorough revision. Personally the author believes that the same principles should be applied to botanical nomenclature that have been adopted by zoölogists.

To Dr. H. E. Hasse, surgeon of the National Soldiers' Home near Santa Monica, California, I wish to express my profoundest gratitude; without his active cooperation my material would have been of little value. To Dr. A. Zahlbruckner, of the Royal Botanical Museum, Vienna, Austria, I owe a debt not second to that due Dr. Hasse. Each of the above has gone over a duplicate set of my material and revised my determinations, with a few exceptions which are noted in each case. Professor Clara E. Cummings, of Wellesley College, has also kindly determined material. For the keys and descriptions I alone am responsible.

To Mr. LeRoy Abrams I am indebted for the use of his herbarium and for material from southern California. To Dr. G. J. Peirce, of Stanford University, I am indebted for literature otherwise inaccessible, and for many valuable suggestions. To Professor William R. Dudley, head of the department of systematic botany in Leland Stanford Junior University, I owe, besides material favors such as literature and specimens, the encouragement and guidance which have made this paper possible.

STANFORD UNIVERSITY, September, 1905.

ARTIFICIAL KEY TO GENERA OF THE FOLIACEOUS AND FRUTICOSE LICHENS OF THE SANTA CRUZ PENINSULA, CALIFORNIA.

1. *Foliaceous Lichens.*

a. Thallus gelatinous when wet; color always dark; algæ blue-green.
  b. Thallus without distinct cortical layer; generally dark green. XV. *Collema*, 375.
  bb. Thallus with distinct cortical layer; usually lead-colored. XVI. *Leptogium*, 379.
aa. Thallus not gelatinous when moist.
  c. Apothecia never present.
    d. Thallus dark.
      e. Plant black, with black granules; beneath pale, villous, with white cyphels............................X. *Sticta*, 367.
      ee. Plant dark brown; sub-fruticose; the ascendant irregularly-cut lobes with narrow white edges.....II. *Cetraria*, 336.
    dd. Thallus green or pale.
      f. Plant yellowish green with gray soredia; beneath villous, between naked pale spots....................X. *Sticta*, 367.
      ff. Plant more or less orbicular, at length very large; gray, yellowish or bright green; beneath black, usually brown-margined, more or less black fibrillose. VII. *Parmelia*, 350.
  cc. Apothecia usually present.
    g. Thallus attached at a single point near the center by an umbilicus.
      h. Apothecia visible to naked eye; thallus large or of medium size.
        i. Apothecia adnate, gyrose; thallus brown. IX. *Gyrophora*, 365.
        ii. Apothecia immersed, appearing as minute dark specks on the ashy-gray thallus..XXII. *Dermatocarpon*, 393.
      hh. Apothecia not visible to naked eye; thallus very small, olive, with bluish edges ....XIII. *Endocarpiscum*, 374.
    gg. Thallus attached by numerous rhizoids, not umbilicate.
      j. Apothecia adnate on under side of marginal lobes. XI. *Nephromium*, 370.
      jj. Apothecia always on upper surface of thallus.
        k. Thallus bright yellow or orange.
          l. Apothecia chestnut; spores simple, colorless. II. *Cetraria*, 336.

ll. Apothecia yellow or orange; spores bilocular, colorless.
VI. *Theloschistes*, 347.

kk. Thallus not bright yellow or orange.

m. Thallus horizontal, orbicular or variously lobed; under surface with veins or cyphels.

n. Thallus pale or whitish beneath, with brown veins and fibrils; apothecia adnate on tips of more or less elongate lobes............XII. *Peltigera*, 372.

nn. Thallus pale villous beneath, with large pale naked spots or small white cyphels......X. *Sticta*, 367.

mm. Without veins or cyphels on under surface.

o. Spores simple, colorless.

p. Thallus flat, usually appressed; under surface brown or black, more or less clothed with black fibrils; apothecia scattered over surface of plant.....................VII. *Parmelia*, 350.

pp. Thallus sub-fruticose, compressed; apothecia marginal or on tips of ascendant lobes.
II. *Cetraria*, 336.

oo. Spores bilocular, brown.........VIII. *Physcia*, 359.

2. *Fruticose Lichens.*

Plants more or less erect and shrub-like, or drooping and pendulous.

a. Thallus of two kinds: (1) a horizontal, more or less leafy or granulose one; (2) a more prominent, erect, and caulescent one, simple and club-, cup- or funnel-shaped, or slender and much branched; apothecia, when present, scarlet or brown.
XIX. *Cladonia*, 386.

aa. Thallus uniform; not two-fold.

b. Apothecia globose, terminal; plant tufted, shrub-like, gray.
XXI. *Sphærophorus*, 392.

bb. Apothecia dish- or shield-like; terminal, marginal, or more rarely scattered.

c. Thallus hair-like.

d. Brown or black, like tangled mats of fine hair; on shrubs and trees; sterile.........................V. *Alectoria*, 346.

dd. Color not black or brown.

e. Thallus erect or decumbent, densely tufted, intricately branched, terete, gray; sterile; on maritime rocks.
XX. *Dendrographa*, 392.

ee. Thallus coarser, gray or pale straw-color, rarely red;

tufted or pendulous, becoming enormously elongated; apothecia concolorous or pale tan, with fibrillose margin .... IV. *Usnea*, 342.

cc. Thallus not resembling hair.

f. Plants not gray or green.

g. Thallus brown or black.

h. Sooty black, small, shrub-like, compact, sterile; on perpendicular sandstone rocks..XIV. *Ephebe*, 375.

hh. Greenish black or brown, spreading, compressed; apothecia abundant, terminal; on old fences, shrubs, and trees .... II. *Cetraria*, 336.

gg. Thallus yellow.

i. Spores simple, colorless; thallus bright lemon-color; apothecia chestnut .... III. *Evernia*, 341.

ii. Spores polar-bilocular, colorless; plants and apothecia reddish yellow or orange.

j. Thallus lax, spreading, pendulous or decumbent; on trees and maritime rocks; apothecia scattered or marginal....... .... VI. *Theloschistes*, 347.

jj. Thallus short, rigid, becoming decumbent; apothecia terminal; on maritime rocks.
XVII. *Placodium*, 383.

ff. Plants gray, green, or pale.

k. Apothecia present.

l. Apothecia concolorous; thallus tufted, compressed or terete, or elongate, pendulous, and greatly compressed .... I. *Ramalina*, 331.

ll. Apothecia not colored like thallus.

m. Apothecia chestnut; thallus lobes long, ascendant, white beneath; on trees...... II. *Cetraria*, 336.

mm. Apothecia yellowish, dusky, or red; plants very short, stout, erect, rigid, sub-crustaceous; on maritime rocks............ XVIII. *Lecanora*, 384.

kk. Apothecia absent.

n. Thallus not pendulous or decumbent.

o. Thallus erect, the narrow lobes margined with stout branching fibrils; on earth..VIII. *Physcia*, 359.

oo. Sub-crustaceous; short, stout, terete, powdery; simple or branched; on maritime rocks.
XVIII. *Lecanora*, 384.

nn. Thallus pendulous or erect; more or less white sorediate; on trees and shrubs .. ...III. *Evernia*, 341.

I. **Ramalina** Acharius.

Apothecia shield-like, scattered, marginal, or terminal, subpedicellate, concolorous; spores ellipsoid or curved, colorless, bilocular. Thallus fruticose, tufted, erect or pendulous, terete or compressed, alike on both sides; color pale green, varying from white or gray to a yellowish glaucous green.

Ramalina Ach. Lich. Univ. 122. 1810.

KEY TO THE SPECIES.

a. Habitat, maritime rocks.
  b. Thallus terete, smooth or wrinkled.
    c. Sparingly branched, blackening at base; apothecia lateral. 1. *ceruchis*, 331.
    cc. Thallus much shorter than above, simple; not blackening; apothecia terminal................ .... 3. *combeoides*, 332.
  bb. Thallus compressed. two-edged..................4. *homalea*, 332.
aa. Habitat, trees, shrubs, fences.
  d. Apothecia abundant.
    e. Thallus a lace-like net-work, long, pendulous, much branched and tangled............... ....5. *reticulata*, 333.
    ee. Thallus tufted, erect or pendulous, little branched, compressed, two-edged, not servediate ....6. *menziesii*, 334.
  dd. Apothecia rare, inconspicuous, or none.
    f. Apothecia never present; thallus terete, thread-like, with conspicuous bluish soredia; on maritime trees, shrubs, and old fences .:............................2. *ceruchis cephalota*, 332.
    ff. Apothecia rare or inconspicuous.
      g. Plants tufted, erect or pendulous, compressed, two-edged or linear; white or pale soredia abundant. 7. *farinacea*, 335.
      gg. Thallus very small, erect, tufted, much branched, with filiform tips; soredia not present.........8. *rigida*, 335.

1. RAMALINA CERUCHIS (Ach.) DeNot.

Thallus tufted, terete, smooth, becoming wrinkled; sparingly branched, the tips pointed; color yellowish green, basally black or blackening; apothecia (not seen) lateral.

The long, cylindrical, pointed thallus of this species serves to separate it very markedly from the other Ramalinas.

I have obtained the typical form but once, and then it was sterile. It occurs very sparingly on the sandstone cliffs above the sea at Sutro Heights, San Francisco.

Parmelia ceruchis Ach. Meth. Lich. 260. 1803.
Borrera ceruchis Ach. Lich. Univ. 504. 1810.
Ramalina ceruchis DeNot. Giorn. Bot. Ital. 1: 45. 1846.

2. RAMALINA CERUCHIS CEPHALOTA Tuckerman.

This subspecies is known at once by the conspicuous, lateral, bluish soredia which abound on the very slender, short, round, entangled filaments. It is always sterile. It occurs all along the Pacific coast within our territory, growing on dead or dying twigs and branches of maritime trees and shrubs, and on old fences. It was first collected at Santa Cruz, by Dr. C. L. Anderson, who supplied Tuckerman with his specimens.

I have collected specimens at Point San Pedro and at Pacific Grove on trees and shrubs, and along the coast near Pigeon Point on old fences.

Ramalina ceruchis f. cephalota Tuck. Syn. N. Am. Lich. 1: 21. 1882.

3. RAMALINA COMBEOIDES Nylander.

Thallus tufted, short, stout, terete; color a pale glaucous green; no part of the thallus black; apothecia abundant, terminal; concolorous, or slightly yellowish.

Habitat, maritime rocks.

This species is placed with *Ramalina ceruchis* by Tuckerman, but there seems to be no difficulty in separating the two forms in the field. They differ constantly in color, appearance of thallus, size, and in the apothecia. The short cylindrical thallus, capped by the disk-shaped apothecia, together with the sage-green color and absence of black, distinguish it from all related forms.

This species is very abundant about Point San Pedro, on rocks 200 or 300 feet above the Pacific Ocean.

Ramalina combeoides Nyl. Bull. Soc. Linn. Norm. II. 4: 107. 1870.

4. RAMALINA HOMALEA Acharius.

Thallus tufted, compressed, two-edged, smooth or becoming wrinkled; lobes spreading, simple or irregularly branched;

apothecia abundant, marginal or sub-terminal; color, yellowish-green; apothecia concolorous, or decidedly yellowish; hold-fast and basal portion of plant filled with red or orange coloring matter. The living plant is perhaps a gray-green, the yellow tinge coming out more strongly in herbarium specimens.

Habitat, maritime rocks.

This singular looking *Ramalina* occurs all along the coast of California, wherever conditions are favorable. In places it covers the rocks to such an extent that at some distance they seem to be hidden from view by some kind of tufted grass.

The holdfast is very strong and often brings a layer of rock away with it. It contains a remarkable amount of orange-red coloring matter and no doubt would furnish a satisfactory orchil.

Specimens have been obtained at Golden Gate, San Francisco, Point San Pedro, Pilarcitos Creek Cañon about two miles from the ocean, and at Pebble Beach, Pescadero. I have examined specimens in the University herbarium from Santa Cruz Island, off the coast of California near Santa Barbara, collected by Mr. R. E. Snodgrass, and from Guadalupe Island, Lower California, collected by the late Dr. W. W. Thoburn. *Ramalina homalea* Ach. Lich. Univ. 598. 1810.

5. RAMALINA RETICULATA (Noehd.) Krempelh.

Lace Lichen.

Thallus much compressed, greatly elongated, pendulous; very much branched, forming tangled mats: the whole plant filled with holes, the result being a more or less coarse or delicate net-work; the branches giving off many lobules, also reticulated; color grayish green, alike on both sides. Apothecia abundant, scattered over surface of plant, concolorous.

This giant lichen is found throughout our range, but reaches its greatest development in the lower foothills around San Francisco Bay. It is common on trees and old fences, but grows best on the deciduous oaks and the buckeye, *Æsculus californica*.

In deep dark humid cañons, or at great elevations where subject to the influence of the prevailing ocean fogs and winds, the thallus is exceedingly delicate and filmy, resembling the finest lace. In the dry lowlands the plant is often very coarse, the broad unperforated expansions of the thallus reaching a breadth of 40 mm. or more. In favorable locations *Ramalina reticulata* may reach a length of at least two meters and a breadth of two-thirds of a meter.

The apothecia are produced in profusion and many specimens can be found attached by the holdfast from which they have grown, but the chief method of propagation and diffusion is by the tearing or breaking of the thallus and the dissemination of the fragments by the wind. This method goes on at all times, fragments constantly breaking off and floating downward even during the dryest and calmest weather. Alighting on any object, the fragment soon becomes greatly entangled through the hygroscopic action of its hyphæ.

The oaks are often completely covered with festoons of this lichen, so that they present an appearance identical with that of the live oaks of the Gulf States, covered with *Tillandsia usneoides*.

Lichen reticulata Noehd.; Schrad. Journ. Bot. 1800: 238. 1801.

Ramalina reticulata Krempelh. Geschicht. u. Litt. d. Lich. 1: 86. 1867.

6. RAMALINA MENZIESII Tuckerman.

Thallus originally tufted, rigid, linear, canaliculate; lobes more or less twisted, irregularly branched; puberulent or smooth. With age the plant becomes more or less flaccid and pendulous, the lobes long, dilated and ribbon-like, more or less irregular in outline, the edges fringed occasionally with lobules; surface furrowed and channelled; color sage-green, gray-green, or bright green. Apothecia abundant, at first marginal or subterminal, later scattered; small to large, sub-pedicellate, margin usually incurved.

Habitat, trees, shrubs, and old fences. It is apparently not found in the higher mountains, but is exceedingly abundant throughout the plains and foothills.

This remarkable *Ramalina* attains a length of four or five inches on trees, but reaches its maximum development on the windward, shady side of old fences bordering the salt marshes about San Francisco Bay. Specimens from near Mountain View landing are over 25 cm. long, with lobes reaching a breadth of 16 mm. The largest apothecia seen were 10 mm. in diameter, but this is exceptional. The long, ribbon-like plants produce apothecia no larger than do those of only an inch in height.

Ramalina menziesii Tuck. Syn. Lichens New Eng. 12. 1848.

7. RAMALINA FARINACEA (L.) Ach.

Thallus tufted, erect or pendulous, compressed and two-edged, or attenuate and thread-like, channeled; color pale green to almost white; lateral white powdery soredia very abundant on lobes. Apothecia lateral, rare and inconspicuous, concolorous; spores curved.

Throughout the foothills and mountains, on trees and shrubs. A few fruiting specimens were obtained on oaks in the mountains above Searsville, at an altitude of 1500 feet.

This plant is likely to be overlooked or confused with *Evernia prunastri*, with which it is commonly associated. *Ramalina farinacea*, *Evernia prunastri*, *Usnea florida*, and *Usnea hirta* clothe densely the twigs of trees in the foothills, converting them into gray brushes.

Lichen farinaceus L. Sp. Pl. 2: 1146. 1753.
Ramalina farinacea Ach. Lich. Univ. 606. 1810.

8. RAMALINA RIGIDA Ach.

Thallus small, tufted, erect, irregularly much branched, terete or flattened and somewhat channelled; the branches slender, thin, their tips filiform; color white to greenish white. Apothecia small, lateral, the disk greener than the thallus; spores ellipsoid, $\frac{12 \text{ to } 16}{6 \text{ to } 7}$ mic.

This pretty little *Ramalina* occurs on the trunks of alders along Los Gatos Creek near Wrights, at about 800 feet, and in Austrian Gulch at 1500 feet. It is found very sparingly, growing with *Ramalina farinacea* and *Evernia prunastri*, with young stages of which it is likely to be confused and hence overlooked in collecting.

My largest specimens do not exceed three-fourths of an inch in height. Two fruiting specimens were found in Austrian Gulch.

It will probably be found beside all perennial streams in deep and shady cañons.

Identification by Dr. Hasse.

Ramalina rigida Ach. Syn. Meth. Lich. 294. 1814.
Lichen rigidus Pers. in Ach. l. c. as syn.

II. **Cetraria** (Acharius) Fries.

Thallus fruticose, or in most of our species expanded foliaceous, with lobes more or less ascendant, narrowed and elongate; medullary layer cottony; color very variable, green, white, yellow, brown and black. Apothecia, except in number one, darker and of a different color from that of the thallus; terminal or marginal; spores simple, ellipsoid, colorless.

Cetraria Ach. Meth. Lich. 292. 1803; in part. Lich. Univ. 96. 1810.
Dufourea Ach. Lich. Univ. 103. 1810; in part.
Cornicularia Ach. Lich. Univ. 124. 1810; in part.
Cetraria Fries, Lich. Europ. Reform. 34. 1831.

KEY TO THE SPECIES.

a. Thallus black or greenish black.................1. *californica*, 337.
aa. Thallus variously colored.
  b. Thallus not green or pale.
    c. Thallus yellow. ....8. *juniperina*, 340.
    cc. Thallus some shade of brown.
      d. Apothecia abundant.
        e. Thallus greenish to dark brown; lobes ascendant, crowded, finally narrowed...... .... 2. *ciliaris*, 337.
        ee. Thallus dark brown; lobes broad, flat, but little ascendant....................................3. *platyphylla*, 338.
      dd. Always sterile; lobes with white sorediate edges. 4. *chlorophylla*, 338.
  bb. Thallus green or pale.
    f. Foliaceous; green, more or less black basally beneath; edges laciniate; surface sorediate.....................6. *glauca*, 339.
    ff. Fruticose; lobes long, narrow, ascendant or pendulous.
      g. Apothecia abundant, terminal; lobes white beneath. 5. *lacunosa stenophylla*, 339.

gg. Sterile; lobes broad, foliaceous, black beneath, becoming linear and white beneath............7. *tuckermani*, 340.

1. CETRARIA CALIFORNICA Tuckerman.

Thallus tufted, fruticose, erect; lobes spreading, flattened or linear, much branched, their tips finely dissected; color black or very dark green; occasionally brownish green or dusky; dull; beneath paler, usually olive green or brown, but varying greatly; finally white with a tinge of greenish. Apothecia terminal; margin toothed or fringed, sometimes almost smooth; concolorous and dull, but sometimes shining and darker than the thallus.

On fences, shrubs, and twigs of trees.

Found everywhere; most abundant on *Adenostoma*, at an elevation of 1800–2000 feet. Our specimens small or dwarfed when compared with those from other parts of the state. The largest and most typical plants with us occur on sheltered fences.

I have specimens obtained at all elevations from the salt marshes about San Francisco Bay to 3788 feet.

Cetraria californica Tuck. Am. Jour. Sci. 28, 203. 1859; Syn. N. Am. Lich. 1: 29. 1882.

2. CETRARIA CILIARIS (Ach.) Tuck.

Thallus foliaceous, depressed, expanded, irregularly cut and lobed; lobes expanded and leafy, or more often narrowed, crowded, ascendant, and much dissected; margin of lobes not ciliate, but crenate, and margined with minute black or dark tubercles; similar tubercles often appearing on the surface of lobes, or even covering them; color dusky brown, but varying from bright to dusky green, brownish, and dark brown; beneath brownish, wrinkled and pitted, and with occasional fibrils. Apothecia terminal or marginal; disk chestnut; margin crenulate or minutely tuberculate.

Habitat, trees, shrubs, and fences. Abundant throughout; I have specimens from all altitudes from sea-level to 3000 feet.

A careful examination of many specimens has failed to show any according in character with the specific name, marginal cilia or fibrils being invariably absent.

A particularly luxuriant but aberrant form is found on fences along the Pacific coast. It is distinguished by its large clumps of erect, complicated, and crisped lobes, and great development of the tubercular or cephaloid growths mentioned above, the entire surface being covered with them. This form is usually sterile, though sometimes apothecia are abundant.

Cetraria ciliaris Ach. Lich. Univ. 508. 1810; Tuck. Syn. N. Am. Lich. 1: 34. 1882.

3. CETRARIA PLATYPHYLLA Tuckerman.

Thallus thin, compressed, foliaceous, rigid; lobes appressed and expanded, with elevated tips, or more often ascendant, narrow at base; surface rough, covered with tubercles, the lens also often disclosing the presence of many sulphur-colored granules; color dull dark olivaceous brown; under surface paler, wrinkled; medullary layer sulphur-colored or white and cottony. Apothecia marginal; disk shining, darker than thallus; margin tuberculate.

A limb of *Pseudotsuga taxifolia*, brought from the Butano Ridge by Professor Dudley, has on it several plants of this species, growing with *Parmelia enteromorpha*. This came from an altitude of about 2000 feet. This specimen has the medullary layer cottony, with no trace of the sulphur-color mentioned by Tuckerman. It does, however, have many minute sulphur-colored grains scattered over the surface of the thallus.

A single sterile specimen was collected by the author on Loma Prieta, altitude 3788 feet, growing on *Adenostoma*. In this specimen the medullary layer is sulphur-colored.

Identification by the author.

Cetraria platyphylla Tuck. Syn. N. Am. Lich. 1: 34. 1882.

4. CETRARIA CHLOROPHYLLA (Humb.) Wahl.

Thallus foliaceous, expanded; lobes numerous, short, irregularly cut; terminally ascendant, sinuate, crenate, with white sorediate edges; color varying from olivaceous or greenish dull brown to a shining chestnut, and darker; beneath paler, wrinkled, and with occasional scattered fibrils.

Always sterile with us.

Common on fences throughout the foothills and to the summit of the range.

This species may be recognized at once by the narrow but conspicuous white edge of the thallus.

Lichen chlorophyllus Humboldt, Fl. Fri. Spicil. 20. 1793.
Cetraria chlorophylla Wahl.

5. CETRARIA LACUNOSA STENOPHYLLA Tuck.

Thallus becoming fruticose, deeply and irregularly lobed; lobes long, lax or sub-pendulous, narrow to linear, deeply channelled; margins laciniate, erose, and minutely tuberculate; color pale sage-green or gray-green; some specimens with a brownish cast; beneath white, or very pale. Apothecia terminal; disk chestnut; margin crenate or more rarely entire.

Habitat, trees.

Very common in the mountains above 1500 feet. Especially abundant on the limbs of *Pseudotsuga taxifolia*, which it sometimes clothes to the exclusion of all other lichens.

Cetraria lacunosa stenophylla Tuck. Syn. N. Am. Lich. 1: 35. 1882.

6. CETRARIA GLAUCA (L.) Acharius.

Thallus membranaceous, foliaceous, sinuately or irregularly broad-lobed; the crenate or dissected edges of the lobes frequently serediate, thickened, and prolonged into more or less conspicuous coralloid branchlets; color of plants growing on earth: greenish gray marginally, varying to olive- or brown-gray centrally, or sometimes the whole plant a glaucous gray-green; beneath wrinkled or reticulate and black, with now and then a chestnut margin; fibrils wanting, or occasionally scattered and very minute.

Color of plants on trees: pale sage-green, varying to colors as dark as those of earth-growing forms. Beneath black, fading into pale brown, with broad white margins.

Always sterile with us.

Everywhere on trees in the mountains above 1,500 feet, but at no place very abundant. Usually on the limbs of *Pseudotsuga taxifolia*, mixed with *Usneas*, *Sphærophorus globosus*, and *Cetraria lacunosa stenophylla*.

This lichen also occurs at slight elevations, on earth in rock crevices. I have specimens from Pilarcitos Creek Cañon, at an altitude of 250 feet.

Lichen glaucus L. Sp. Pl. 2 : 1148. 1753.
Cetraria glauca Ach. Meth. Lich. 296. 1803.

7. CENTRARIA TUCKERMANI Herre, nom. sp. nov.

This form differs from *C. glauca* in having the lobes elongated, lax, narrow or linear, and more or less channelled; margin irregularly cut and erose; beneath black or dark brown basally, the lobes white below. Sterile with us.

Habitat: On *Pseudotsuga taxifolia.*

Collected but once, near King's Mountain House, at the head of Purissima Creek, at an altitude of 1900 feet. No doubt it occurs all along the summit of the range mixed with *C. lacunosa stenophylla* and *C. glauca.*

Cetraria glauca stenophylla Tuck. Syn. N. Am. Lich. 1 : 36. 1882; name preoccupied.

8. CETRARIA JUNIPERINA (L.) Acharius.

Thallus foliaceous, membranaceous and expanded, or else tufted, irregularly cut-lobed and ascendant; lobes crowded, edges erose and crenate. Apothecia submarginal, the disk chestnut; margin crenulate or tuberculate.

This lichen is known at once by its bright yellow color, alike on both sides; sometimes the yellow is tinged with greenish.

Very abundant on the twigs and limbs of *Pinus radiata* (*P. insignis*) at Pacific Grove, especially on dead wood. This is extra-limital, being on the southern shore of Monterey Bay. It also occurs in the mountains near San Juan, below the Pajaro River; this is just across from the southern extremity of the Santa Cruz peninsula. I have no doubt however that it occurs somewhere along the coast between Santa Cruz and Pescadero, as *Pinus radiata* is found there also, and the conditions are similar to those at Pacific Grove.

Lichen juniperinus L. Sp. Pl. 2 : 1147. 1753.
Cetraria juniperina Ach. Meth. Lich. 298. 1803.

III. **Evernia** Acharius.

Thallus tufted, fruticose, erect, becoming finally long and pendulous; terete and angular basally, or else leafy and flattened; branched or lobed; medullary layer cottony; color, lemon-yellow, or pale green. Apothecia, when present, subterminal or marginal, the disk chestnut; the margin often fibrillose.

Spores simple, colorless, ellipsoid.

With us, fruiting specimens are very rare.

Evernia Ach. Lich. Univ. 84. 1810.

1. EVERNIA VULPINA (L.) Acharius.

Thallus tufted, erect, much branched, becoming long and pendulous; branches terete, basally angular; large specimens conspicuously angular and lacunose; whole plant a bright lemon-color: very small, immature specimens sometimes of a yellowish green. Apothecia large, terminal, more or less pedicellate; disk chestnut; margin often fringed with large fibrils, otherwise smooth and entire.

On trees, old fences, and sandstone.

Occurring everywhere on the Santa Cruz peninsula, though never attaining a length greater than 3 inches. Small, inconspicuous specimens are found on old fences and roofs from the salt-marshes about San Francisco Bay to the summit of the range. At the head of Devils Cañon, at an altitude of 2300 feet, it occurs in considerable abundance on *Pseudotsuga taxifolia;* here it is also common on sandstone as also at Castle Rock, altitude 3000 feet. On Loma Prieta (3788 feet) it occurs on dead limbs of *Adenostoma fasciculatum.*

I have but one fertile specimen from the Santa Cruz peninsula, found on an old fence near Stanford University, at an altitude of 200 feet.

In the Santa Lucia Mountains, San Luis Obispo County, and in the Sierra Nevada Mountains, it forms huge, matted, yellow clumps 6 inches or more in length, fruiting in the greatest profusion.

Used as a dye-stuff in the valley of the Willamette, Oregon, where its growth is also luxuriant.

Lichen vulpinus L. Syst. Nat. ed. 10. 2: 1343. 1759.
Evernia vulpina Ach. Lich. Univ. 443. 1810.

2. EVERNIA PRUNASTRI (L.) Acharius.

Thallus tufted, fruticose, erect or pendulous, angular or flattened; branches numerous, narrow to linear, elongate; or (forma *sorediféra* Ach.) shorter and much wider lobed, beneath lacunose or channelled; white or greenish, mealy, lateral and confluent soredia very abundant; also more or less present in the typical form; color whitish, pale green, to dark green; beneath much paler, often white.

Sterile with us.

A very common lichen throughout our territory, growing on trees, shrubs, dead wood, fences, roofs, mossy stones. Forming conspicuous whitish tufts on twigs.

Lichen prunastri L. Sp. Pl. 2: 1147. 1753.
Evernia prunastri Ach. Lich. Univ. 442. 1810.

IV. **Usnea** (Dill.) Ach.

Thallus shrub-like and erect or excessively elongated lax and pendulous, terete, much branched, smooth or roughened, with or without many short fibrils; medullary layer solid, white, cord-like; color pale gray, silver-green, or straw-color, except in one form which is red; alike on all sides. Apothecia tan, pale flesh-color, or concolorous, orbicular, peltate, terminal or lateral; the margin radiately fibrillose; spores simple, colorless, ellipsoid, small.

On trees and shrubs throughout; occasional on old fences and roofs. Reaching the maximum thalline development and number of species at high altitudes where exposed to fog.

The species not always well defined and apparently intergrading. One species not heretofore described is rather common over part of our territory.

Usnea Dillenius, Musc. 56. 1741; in part.
Usnea Ach. Meth. Lich. 306. 1803.

KEY TO THE SPECIES.

a. Plants small, erect, shrub-like.
  b. Color gray-green.
    c. Without soredia ....1. *florida*, 343.

cc. Soredia more or less abundant.....................2. *hirta*, 343.
bb. Color rusty red.....................................3. *rubiginea*, 343.
aa. Plants more or less pendulous.
d. Suberect or short-pendulous.........................4. *ceratina*, 344.
dd. Pendulous, tangled, long to very long.
e. Fibrils numerous.
f. Thickly set with short spreading fibrils...5. *dasypoga*, 344.
ff. Fibrils nearly straight, horizontal.......7. *longissima*, 345.
ee. Fibrils very few or wanting.
g. Without spreading fibrils.......................6. *plicata*, 344.
gg. Smooth or with very few fibrils; plant stout and coarse. 8. *californica*, 345.

1. USNEA FLORIDA (L.) Ach.

Thallus terete, tufted, erect, stout, rather rigid, shrub-like, spreading-branched, beset with stiff, straight fibrils; epidermis smooth or more or less roughened with minute papillæ or tubercles; color gray-green. Apothecia medium to very large, numerous, terminal; color a pale tan, very pale flesh-color, or sometimes whitish.

On trees and fences throughout. Dwarfed and usually sterile near sea-level; larger and fruiting profusely above 1000 feet.

Lichen floridus L. Sp. Pl. 2: 1154. 1753.
Usnea florida Ach. Meth. Lich. 307. 1803.

2. USNEA HIRTA (L.) Hoffm.

Thallus small, tufted, shrub-like, erect, rigid; branches widespread, curving, thickly clad with short fibrils; the whole plant densely beset with soredia. Apothecia small, rare.

On trees and fences throughout, but most frequent in the foothills at moderate elevations.

Lichen hirtus L. Sp. Pl. 2: 1155. 1753.
Usnea hirta Hoffm. Deutsch. Fl. 2: 133. 1795.

3. USNEA RUBIGINEA (Michx.).

Thallus much like that of *Usnea hirta;* epidermis smooth to papillate-scabrous; color varies from bright to dark rusty red or brick-red. Apothecia (not seen) concolorous.

A few insignificant specimens found near the head of Alpine

Creek, at an altitude of 1000 feet. Very abundant and conspicuous on *Pinus radiata* at Pacific Grove, Monterey Bay. Should be carefully looked for along the coast between Santa Cruz and Pescadero.

A very handsome lichen.

Usnea florida rubiginea Michx. Fl. Bor. Am. 2: 332. 1803.

4. USNEA CERATINA Acharius.

Thallus fruticose, much branched, at first erect but becoming pendulous; reaching a length of 6–8 inches or perhaps more; thickly covered with long slender curling fibrils; epidermis smooth to warty or papillose. Apothecia abundant, medium to large; concolorous, tan, or very pale flesh-color.

On trees and dead wood. Abundant at 2000 feet and above.

Specimens collected by Dr. Peirce on the La Honda grade were identified by A. B. Seymour of Harvard University. Specimens collected at Castle Rock and elsewhere identified by the author; for lack of time not submitted to Dr. Zahlbruckner.

Usnea ceratina Ach. Lich. Univ., 619. 1810.

5. USNEA DASYPOGA (Ach.) Nyl.

Thallus greatly elongated and pendulous, slender, terete; thickly beset with short spreading fibrils; epidermis usually smooth or minutely roughened; color gray or yellowish green (straw-color); the principal branches often blackening basally. Apothecia small, infrequent, rather pale.

Common on trees and shrubs above 600 feet; best developed in the redwood formation, often reaching a length of four feet.

Usnea plicata dasypoga Ach. Meth. Lich. 312. 1803.

Usnea dasypoga Nyl. St. Gall. Nat. Ges. 202. 1876.

6. USNEA PLICATA (Ach.) Nyl.

Thallus greatly elongated and pendulous, rather coarser than *Usnea dasypoga;* sub-dichotomously divided, the branches without spreading fibrils; varying from gray-green to straw-color. Apothecia very small, rare.

Frequent on trees and shrubs above 600 feet altitude. Often growing in inextricable confusion with *Usnea dasypoga.*

Lichen plicatus Ach. Prodr. 225. 1798.

Usnea plicata Nyl. Flora, 68: 299. 1885.

7. USNEA LONGISSIMA Ach.

Thallus pendulous, finally excessively elongated, terete or basally slightly compressed, sparingly branched; thickly clothed with simple, nearly straight, horizontal, comparatively short fibrils. Apothecia small or very small, lateral or terminal; concolorous or pale tan; color a soft but bright silvery or gray-green; herbarium specimens fading badly, becoming finally a yellowish green.

On trees above 1500 feet, in the redwood formation.

About the head of Purissima Creek, at an altitude of 1900 feet, the long, swaying, silver gray fronds of this lichen form a conspicuous feature of the landscape. Here it attains a length of eight or nine feet, but owing to its inaccessible situation only fragments are obtainable, my largest specimens being but about five feet in length.

Usnea longissima Ach. Lich. Univ. 626. 1810.

8. USNEA CALIFORNICA Herre, sp. nov.

Thallus large, stout, terete, much elongated and pendulous, smooth; the coarse branches irregularly divided and widespread, readily traceable nearly to the extremity of the plant; secondary branches long and sub-divided; sparsely clothed with fibrils; branchlets and fibrils occasionally sorediate; color gray-green to yellowish green. Fruiting specimens rare; apothecia borne on second branches, terminal or lateral, small to medium size; concolorous or tan.

On trees.

As yet only seen about the head of Alpine Creek Cañon at an altitude of 1000 feet; locally abundant.

A robust, conspicuous plant, reaching a length ordinarily of 2–3 feet and probably the bulkiest of our Usneas. Quite different in habit and general appearance from all our other species.

"Species adhuc non descripta, similem in Mexico lectan vidi in herbario Horti Vindobonensi." — Zahlbruckner.

Type, No. 194, Stanford Univ. Herbarium. Cotypes in Royal Botanical Museum, Vienna, Austria; Stanford Univ. Herbarium; Herbarium of Dr. H. E. Hasse; and Herbarium of A. C. Herre. Type locality, head of Alpine Creek Cañon, San Mateo County, California. Coll. A. C. Herre, July 28, 1903.

V. **Alectoria** (Ach.) Nylander.

Thallus pendulous, terete, resembling fine hair; alike on all sides; much and intricately branched, forming tangled mats; color black to dull brown; medullary layer cottony.

Alectoria Ach. Lich. Univ. 592. 1810; in part.
Alectoria Nylander, Syn. Meth. Lich. 1: 277. 1860.

1. ALECTORIA JUBATA (L.) Tuckerman.

Thallus tufted, pendulous, elongated, slender, terete, smooth, polished, very much branched and hair-like, forming tangled clumps and mats; small, greenish, powdery, lateral soredia sometimes present; color black, green-black, or rarely brownish black.

Always sterile with us.

On trees and shrubs, above 1800 feet.

This peculiar plant, resembling mats of fine black hair, is perhaps widely distributed among the Santa Cruz Mountains, but is nowhere really abundant and is readily overlooked.

Found in greatest quantity on Black Mountain on the Page Mill Road (1800 feet), growing on dwarf *Adenostoma* within two feet of the ground. A single small specimen on an oak tree near the summit of Black Mountain, altitude 2500 feet. Occurring also along the summit of the range above Saratoga, at an altitude of 2400 feet and above on *Pseudotsuga taxifolia* and *Quercus agrifolia*. To be looked for throughout on the under side of limbs of Douglas Spruce and oaks, associated with *Cetraria lacunosa stenophylla*, *Cetraria glauca*, and Usneas.

At the Pinnacles, San Benito County, a short distance south of the Santa Cruz Peninsula, this lichen is common and rather conspicuous, occurring on *Adenostoma*.

Lichen jubatus L. Sp. Pl. 2: 1155. 1753; in part.
Alectoria jubata Tuck. Syn. N. Am. Lich. 1: 44. 1882.

2. ALECTORIA FREMONTII Tuckerman.

This species has not yet occurred within our territory but should be carefully looked for in the mountains, above 3000 feet. It is probable that a search of the larger conifers will reveal its presence.

It may be readily distinguished from *Alectoria jubata* by its uniform reddish brown color, and by the greater length and denser matting of its thallus.

Alectoria fremontii Tuck. Syn. N. Am. Lich. 1: 45. 1882. Suppl. 1: 422. 1858–9.

VI. **Theloschistes** Norman.

Thallus foliaceous, fruticose, or only made up of squamules; usually closely appressed and expanded, but in some species tufted and erect, or even pendulous; color, orange or yellow, occasionally pale gray or ash-color. Apothecia shield-like, usually abundant, the disk always yellow or orange; spores ellipsoid and polar-bilocular, or simple; colorless.

This group is distinct from all others except the genus *Placodium*, with which it has several points of resemblance but from which it may generally be distinguished by the much greater development of the thallus.

Theloschistes Norman, Con. Gen. Lich. 16. 1852.

KEY TO THE SPECIES.

a. Thallus fruticose; erect, decumbent, or pendulous. 1. *flavicans*, 347.

aa. Thallus foliaceous.
- *b*. Spores polar-bilocular, 8.
  - *c*. Thallus pale or bright yellow or orange; more or less orbicular.
    - *d*. Lobes short, thick, crenate, often pruinose. 2. *parietinus*, 348.
    - *dd*. Lobes many cleft.
      - *e*. Thallus small, effuse or stellate; more or less concealed by the small, very abundant apothecia. 3. *polycarpus*, 348.
      - *ee*. Thallus with granulose, powdery margins; apothecia numerous, large..............4. *lychneus laciniosa*, 349.
  - *cc*. Thallus minute or small, effuse, scattered..5. *ramulosus*, 349.
- *bb*. Spores simple or 1-septate, 20 to 60 in the thekes. 6. *concolor*, 349.

1. THELOSCHISTES FLAVICANS (Sw.) Norm.

Thallus tufted, elongated, erect and spreading, becoming decumbent; branches numerous, narrow to linear, more or less twisted and pitted or channelled; margins with numerous small, concolorous soredia. Apothecia rare, without marginal radial fibrils; disk a very dark orange; color of thallus a bright orange-yellow.

On rocks and earth.

Only found thus far in Pilarcitos Creek Cañon, at an altitude of 200 feet; where it is rather abundant on a sandstone cliff, mingled with *Ramalina homalca*, *Sphærophorus globosus* *Cetraria glauca*, *Sticta scrobiculata*, *Physcia leucomela*, *Parmelia flavicans*, and Cladonias.

My specimens were compared with those in the Tuckerman herbarium at Harvard by Professor Clara Cummings, of Wellesley. Given by Tuckerman as growing on trees, but not apparently doing so with us. The tree form is abundant farther south in the coast ranges near Santa Barbara and in San Luis Obispo County, on the twigs of various trees and shrubs. The specimens collected there by Professor Dudley are darker colored and the apothecia are numerous.

Lichen flavicans Swartz, Fl. Ind. Occid. 3: 1908. 1788.
Theloschistes flavicans Norm. Gen. Lich. 17. 1852.
Physcia flavicans DC. Fl. Fr. 2: 189. 1805; Crombie, Brit. Lich. 1: 295. 1894.

2. THELOSCHISTES PARIETINUS (L.) Norm.

Thallus foliaceous, more or less orbicular, appressed; lobes short, blunt, thick, crenate; somewhat pruinose. On fences sometimes forming a thick, effuse crust; color yellow to orange. Apothecia inconspicuous, small to medium size; margin thick, prominent, entire, becoming flexuous; finally disappearing; disk concolorous.

On trees, rocks, roofs, and fences.

Common in the lowlands and foothills about San Francisco Bay, seemingly best developed on *Quercus lobata*.

Lichen parietinus L. Sp. Pl. 2: 1143. 1753.
Theloschistes parietinus Norm. Nyt. Mag. Naturvid. 7: 229. 1853.

3. THELOSCHISTES POLYCARPUS (Ehrh.) Tuck.

Thallus very small, sub-orbicular, stellate, or more often effuse, closely appressed, yellow; lobes much cleft, narrow.

Apothecia small and very numerous, sometimes covering the thallus: disk concolorous or orange.

On trees. Common in the valleys and lower foothills.

Lichen polycarpus Ehrhart, Plant. Crypt. Exs. No. 136. 1785.
Theloschistes polycarpus Tuck. Syn. N. Am. Lich. 1: 50. 1882.

4. THELOSCHISTES LYCHNEUS LACINIOSA Schaer.

Thallus foliaceous, appressed, orbicular or stellate, expanded; lobes much and intricately dissected, their tips ascendant and more or less fibrillose; lobes either smooth or with granulose, powdery margins. Apothecia abundant, medium to large, their disks dark orange; margins entire or minutely crenulate; color of thallus yellow to orange, rarely greenish to whitish; beneath white or greenish white, with scattered fibrils of the same color.

Habitat, trees and dead wood; especially noticeable on *Æsculus californica*.

Very abundant in the valleys and foothills.

5. THELOSCHISTES RAMULOSUS Tuck.

Thallus small, effuse, closely appressed; the minute and scattered lobules but little divided; color pale yellow to greenish yellow. Apothecia very small, entire, concolorous, or at length orange.

On trees and shrubs, in the valleys and foothills.

My specimens were obtained from a pepper tree (*Schinus molle*) in Mayfield, growing with *Theloschistes concolor* and *Theloschistes polycarpus*.

This insignificant little plant is readily overlooked. It resembles *Theloschistes concolor*, from which it may be best distinguished by the difference in spores.

According to Dr. Zahlbruckner this species is only a variety of *Xanthoria lychnea*.

Theloschistes ramulosus Tuck. Syn. N. Am. Lich. 1: 51. 1882.
Xanthoria lychnea ramulosa J. Müll.

6. THELOSCHISTES CONCOLOR (Dicks.) Tuck.

Thallus foliaceous, appressed, the narrow lobes more or less dissected; quite small; color yellow, greenish yellow, or pale; often an ashy white. Apothecia small, yellow to orange; spores numerous, 20 to 60 in the thekes, simple or one-septate.

On trees. An inconspicuous lichen, apparently rare in the valleys and lower foothills. A few scattering specimens were found on *Schinus molle* (pepper tree), growing with *Theloschistes polycarpus* and with *T. ramulosus*. Specimens submitted to Dr. Zahlbruckner were all referable to the two latter species, but unmistakable *T. concolor* was determined by Dr. Hasse as well as by myself.

Lichen concolor Dicks. Pl. Cryt. Brit. 2 : 18, *pl. 9, f. 8*. 1785–1801.

Theloschistes concolor Tuck. Syn. N. Am. Lich. 1 : 51. 1882.

VII. **Parmelia** Acharius.

Thallus foliaceous, appressed, expanded, often very large, variously lobed or laciniate, usually imbricate; the lower surface usually black or dark brown, often brown-margined, generally more or less black fibrillose. Apothecia shield-like, scattered, often sub-pedicellate; the disk usually chestnut; spores small, simple, colorless, ellipsoid or ovoid.

This genus contains the largest and most conspicuous foliaceous lichens of our flora, and is well represented both in number of species and of individuals.

Parmelia Ach. Meth. Lich. 153. 1803.

KEY TO THE SPECIES.

a. Thallus dark.

b. Bright shining brown, to dull brown, nearly black.

c. Soredia absent; on trees and rocks ....9. *olivacea*, 356.

cc. Soredia present.

d. Soredia small; thallus dark, medium to large, on rocks. 10. *sorediata*, 356.

dd. Soredia conspicuous, erumpent; thallus gray to brown; small; on rocks ....11. *conspurcata*, 357.

aa. Thallus some shade of green.

e. Thallus inflated, loosely attached; whitish to bright green.

f. Without perforations in under surface; lobes usually with terminal soredia................................7. *physodes*, 354.

ff. With perforations in under surface; lobes longer, more inflated, without terminal soredia .....8. *enteromorpha*, 355.

ee. Thallus not inflated.

g. Color pale, whitish or glaucous.

h. Under side black, brown-margined; thallus expanded.
  i. Lobes marginally ciliate; thallus medium to very large; glaucous white; on trees and rocks..3. *perforata*, 352.
  ii. Margin not ciliate; thallus small to medium, pearly white; maritime, on fences, roofs, rocks ......1. *perlata*, 351.
hh. Under side not brown-margined; thallus narrowed, branched.
  j. Always sterile.
    k. Thallus not reticulate above; margin ciliate; lobes very narrow, short ....4. *herrei*, 353.
    kk. Surface of thallus reticulate; margin not ciliate; lobes broader, long, many cleft, apically retuse. 6. *saxatilis*, 354.
  jj. Apothecia abundant, margin crenulate; thallus adnate, lobes narrow, sinuate; color bright ...5. *tiliacea*, 353.
gg. Color yellow to yellowish green.
  l. Beneath black, with chestnut or brown border.
    m. Margin of lobes not confluently white sorediate.
      n. Thallus smooth or isidiose-sorediate; on rocks. 2. *flavicans*, 352.
      nn. Surface wrinkled, plicate, with concolorous soredia; on stones and shrubs ....12. *caperata*, 357.
    mm. Edges of lobes confluently white sorediate; surface wrinkled, at least marginally; on trees, fences, roofs. 13. *soredica*, 358.
  ll. Beneath pale or dark, margin darker; surface more or less isidiose; fibrils concolorous, scattered, short. 14. *conspersa*, 358.

1. PARMELIA PERLATA (L.) Acharius.

Thallus greenish pearl-gray, dilated, membranaceous; margin thin, smooth, rounded and irregularly lobulate; rest of thallus thickened, convolute, more or less ascending; margins of inner lobes covered with confluent, concolorous soredia; under surface black, wrinkled, papillose, margin brownish; from strongly and densely black fibrillose to smooth.

Sterile. Apparently confined to a narrow strip along the Pacific coast, not occurring in the mountains or on the Bay shore.

On the roof of an old house on the sea-beach, near Pilar

Point, and also on old fences along the county road from Spanishtown northward for six or eight miles. None was found at an altitude of more than 50 feet and the best specimens grew just above high tide.

Lichen perlatus L. Syst. Nat. ed. 12. 712. 1767.
Parmelia perlata Ach. Meth. Lich. 216. 1803; Lich. Univ. 458. 1810.

2. PARMELIA FLAVICANS Tuckerman.

Thallus large, orbicular, becoming very large and irregular, as in the following species; surface smooth, or centrally more or less wrinkled and plicate; often isidiose-sorediate; lobes long, sinuous, imbricate, marginally crenate and undulate, their tips thin and rounded; color of thallus pale yellow or more often a yellowish green; beneath black, with chestnut margin; smooth or wrinkled; generally naked, but also more or less interruptedly black fibrillose. Apothecia not uncommon; disk chestnut in dried specimens; in the field sometimes of same color as thallus; margin entire or crenulate, often sorediate.

Common on rocks in the foothills.

A well-marked species, not to be confused with any other.

Parmelia perlata flavicans Tuck. Lich. Calif. 13. 1866.
Parmelia flavicans Tuck. Syn. N. Am. Lich. 1: 53. 1882.

3. PARMELIA PERFORATA (Wulfen) Acharius.

Thallus large, finally greatly dilated, smooth, gray, tinged with greenish, or whitish; the ample lobes crenate, becoming marginally much dissected; margins of inner lobes often confluently gray sorediate; lobes fringed (f. *ciliata* Nyl.) with long, black, simple or branched cilia; under side black, with a broad chestnut margin; interruptedly clothed with dense patches of black fibrils. Apothecia rare, medium to large; margin entire; disk chestnut; rarely perforate.

On trees, mossy rocks, and earth.

This large and handsome plant occurs throughout the Santa Cruz mountains, usually sterile. On shaded moss-covered sandstone cliffs immense circular mats are formed; in many cases these coalesce into gigantic carpets covering many square feet.

Fruiting specimens occur in abundance on oaks and *Umbellularia*, about the head of Alpine Creek Cañon, at an altitude of 1000 feet. Nearly all the apothecia found belie the specific name, being imperforate.

Lichen perforatus Wulf. in Jacq. Coll. 1: 116, *pl. 3*. 1786.

Parmelia perforata Ach. Meth. Lich. 217. 1803; Ach. Lich. Univ. 459. 1810.

4. PARMELIA HERREI Zahlbruckner, sp. nov.

Thallus narrow, lobed and deeply dissected; smooth above; the lobes sinuately pinnatifid, their tips rounded or crenate, sometimes sorediate; centrally becoming much complicate and imbricate; margin fringed with long, black, conspicuous cilia. Beneath black and densely clothed with long black fibrils. Surface a dull pearly gray, varying to a slate-gray.

Apothecia not seen.

"*P. sinuosæ* Ach. affinis, differens thallo semper esoredioso, in margine ciliato, KHO supra flavo," Zahlbruckner.

This distinct *Parmelia* has been found but once. A few specimens were found growing on earth in the crevices of sandstone in Pilarcitos Creek Cañon, about two miles from the Pacific, at an altitude of 200 feet. It was mixed with *Parmelia saxatilis*, *Theloschistes flavicans*, *Cladonia furcata racemosa* and *Sphærophorus globosus*.

Specimens are in the herbaria of Leland Stanford Junior University, Dr. A. Zahlbruckner, Dr. H. E. Hasse, and the author. As yet no other specimens have been discovered.

Parmelia herrei A. Zahlbr. *in litt.* 1905.

Type, No. 516 Stanford University Herbarium. Type locality, Pilarcitos Creek Cañon, two miles from the Pacific, Santa Cruz peninsula, Cal. Coll. A. C. Herre, May 28, 1904.

5. PARMELIA TILIACEA (Hoffm.) Ach.

Thallus much narrowed, membranaceous, often suborbicular; smooth, becoming finely wrinkled; closely adherent to the substratum; lobes contiguous, often subimbricate, sinuous, deeply incised; margins crenate or rounded; color gray, varying from nearly white to green, but always of a peculiarly bright, clean appearance; beneath black; densely clothed with small black fibrils. Apothecia abundant, mostly central; disk bright chestnut; margin entire, crenate, or crenulate, or even lobed.

This beautifully colored lichen is very abundant on oaks and buckeyes at an altitude of 2000 feet and upward. It occurs in special abundance about the summit of Black Mountain, at an altitude of 2780 feet. Wherever found it is in full fruit.

Lichen tiliaceus Hoffm. Enum. 26, *pl. 16, f. 2.* 1784; in part.
Parmelia tiliacea Acharius, Meth. Lich. 215. 1803.

6. PARMELIA SAXATILIS (L.) Ach.

Thallus narrowed, deeply cleft; lobes long, sinuous, more or less pinnately dissected, or sometimes rather simple and irregularly cut-lobed. Surface reticulate, rimose, at length sculptured and lacunose; often scabrous, becoming isidiophorous; color usually ashy gray, but varying from almost white to green or even a yellow-gray; beneath black, with paler or chestnut tips to the lobes; usually densely clothed with black fibrils. Apothecia small to medium; disk pale chestnut; margin irregular, sub-crenulate or rather entire; in my specimens greenish powdery sorediose. Practically always sterile with us. Of several thousand specimens examined in the field but one was found with fruit. This was growing in Devils Cañon on sandstone (altitude 2300 feet), the specimen having 12 apothecia.

Common on trees and rocks. Rarer in the foothills, where it descends as low as 150 feet, but becoming very abundant as the mountains are ascended. Grows indifferently on dead or live trees and rocks, but reaching its maximum size on moss-covered sandstone.

While there is considerable variation in color, texture, and width of the fronds, all our plants seem to be referable to the type form.

Lichen saxatilis L. Sp. Pl. 2: 1142. 1753.
Parmelia saxatilis Ach. Meth. Lich. 204. 1803.
Parmelia saxatilis Fries, Lich. Europ. Reform. 61. 1831.

7. PARMELIA PHYSODES (L.) Acharius.

Thallus suborbicular, deeply cut, more or less inflated loosely attached to the substratum; lobes numerous, sinuous many cleft, plane or convex; becoming crowded centrally, somewhat ascendant and complicate; ends of lobes often terminating in white soredia; surface smooth, becoming tuberculate; color varying from greenish pearl-gray to slate-color or green; beneath dull black or dusky, much wrinkled; naked; lobes sometimes edged with chestnut. Apothecia more or less cup-shaped; margin crenulate; disk chestnut.

This lichen occurs very sparingly throughout our range; most abundant on old fences and trees at slight elevations.

Lichen physodes L. Sp. Pl. 2: 1144. 1753.
Parmelia physodes Ach. Meth. Lich. 250. 1803.

8. PARMELIA ENTEROMORPHA Acharius.

Thallus suborbiculate, soon becoming large, expanded, and indeterminate; deeply cleft, loosely attached to the substratum; lobes very numerous, more or less inflated, elongated, lax or pendulous, irregularly divided; usually narrow but occurring in all shapes from linear or terete to broad and flat, these last usually short and marginally imbricate; surface smooth and convex, or more rarely wrinkled, sometimes papillate; often densely sprinkled with black specks, the spermogonia; color green, but varying from gray to dingy brownish or even dusky; beneath black or dark brown, wrinkled, without fibrils; more or less beset with holes in the lower cortex. Apothecia usually abundant, medium to large; sub-pedicellate, top-shaped and cup-like, becoming plane or even convex, when the margin disappears; margin entire, crenulate, or lobulate; disk chestnut; often perforate.

On trees, shrubs, and fences.

Very abundant along the summit of the range and extending down in the foothills almost to sea-level. Especially fine on *Sequoia sempervirens* and *Pseudotsuga taxifolia*, being a characteristic lichen of the red-wood forest, growing very rapidly and all the year round. The summer fogs supply it with enough moisture for growth during the dry season and the dense forests protect it from injury by frost during the rainy season.

In the foregoing description the arrangement of Bitter (Hedwigia, 1901) has been followed, including under one head

Tuckerman's *Parmelia physodes c. enteromorpha* and *Parmelia physodes d. vittata*.

Parmelia enteromorpha Ach. Meth. Lich. 252. 1803; Bitter, Hedwigia, 40: 233; t. 11; *pl. 11, 12, 13.* 1901.

9. PARMELIA OLIVACEA (L.) Acharius.

Thallus membranaceous, expanded, orbicular or becoming irregular, appressed; usually smooth and polished, but finally wrinkled, rough, and isidiophorous; lobes rounded, crenate, flat; color olive-brown to very dark brown, almost black; beneath black, with short black fibrils. Apothecia concolorous or chestnut: margin crenate or dentate; very abundant on tree-growing forms, but rare or wanting on those growing on rocks.

Common on rocks, trees, and shrubs throughout.

There is a form (*P. o. panniformis* Nylander) in which the inner lobes become erect or ascendant, irregularly cleft, and densely crowded or imbricate.

This subspecies forms large shaggy patches on the under or protected side of sandstone ledges at Castle Rock and other points on Castle Rock Ridge, at an altitude of 3000 feet and above.

For the determination of this subspecies the author alone is responsible.

Lichen olivaceus L. Sp. Pl. 2: 1143. 1753.

Parmelia olivacea Ach. Meth. Lich. 213. 1803; Ach. Lich. Univ. 462. 1810.

10. PARMELIA SOREDIATA (Ach.) Nylander.

Thallus indeterminate or suborbicular; the marginal lobes much dissected or merely crenate lobulate; centrally wrinkled and folded, more or less imbricate; becoming rough and isidiose, the isidia thickly sprinkled with tiny white soredia; color dark brown; beneath black, with many short black fibrils.

No fertile specimens found.

On rocks throughout, but rare below the summit of the range, and at no place very abundant; my best specimens came from Loma Prieta, at an altitude of 3788 feet.

Similar to *Parmelia olivacea* in form and color, but differing in the presence of soredia and in the chemical reaction. *Parmelia olivacea*, medulla K— C—.

Parmelia sorediata, "medulla C + !" Zahlbruckner.
Parmelia stygia sorediata Ach. Lich. Univ. 471. 1810.
Parmelia sorediata Nyl. Lich. Scand. 102. 1861.

11. PARMELIA CONSPURCATA (Schaer.) Wainio.

Thallus small, orbiculate or irregular; inner lobes somewhat ascendant, their margins often confluently isidiose-sorediate; marginal lobes flatter, rounded, sub-imbricate, crenate; color brown, but varying from ashy gray to chocolate. The whole surface sprinkled with conspicuous, white, erumpent soredia, these passing into the dusky isidiose soredia on older portions of the thallus; beneath brown, varying from buff to black; thickly set with short, shaggy fibrils.

Sterile.

Very abundant on a huge sandstone boulder at the summit of the range on the Bear Gulch road, at an altitude of 1900 feet. Not found elsewhere as yet.

Recorded from Minnesota by Bruce Fink, but not otherwise known from North America.

Parmelia olivacea leucocheilea Mass. Sched. Critt. Lich. Exa. Ital. no. 166. 1855.
Parmelia subargentifera Nyl. Flora, 58: 359. 1875.
Parmelia conspurcata Wainio. Medd. Soc. Faun. Fl. Fenn. 14: 22. 1888.

12. PARMELIA CAPERATA (L.) Acharius.

Thallus large, orbiculate to indeterminate, with smooth but wrinkled and plicate surface; marginally much dissected; lobes long, imbricate, laciniate, their margins often pointed, elevated and roughened, their tips rounded, becoming isidiose centrally or sprinkled with concolorous soredia; color pale yellowish or greenish; beneath black with narrow brown margin; more or less abundantly clothed with short black fibrils. K^{+}_{+} C^{-}_{-}.

Not seen in fruit.

On stones and shrubs, Golden Gate, San Francisco.

A similar lichen, which may prove to be the same, occurs sparingly on twigs along the summit of the range.

Lichen caperatus L. Sp. Pl. 1: 1147. 1753.
Parmelia caperata Ach. Meth. Lich. 216. 1803.

13. PARMELIA SOREDICA Nylander.

Thallus coriaceous, large to very large, orbicular, becoming irregular, undulate, radiately plicate, closely adherent to the substratum; lobes rounded, complicate, imbricate, their margins ascendant and confluently white sorediate, except on periphery where they are dilated, smooth or wrinkled, with crenate edges. Surface of lobes more or less sorediate; central portion of thallus finally passing into sorediate heaps which become detatched and fall away, leaving the outer portions to continue their growth; color green to yellowish green; beneath black, with brown margin; outer lobes sometimes with a few white or dark fibrils. Apothecia abundant on large specimens; generally of small or medium size; disk chestnut; margin entire or lobulate, usually sorediate.

On trees, fences, roofs, and occasional on rocks.

Common everywhere in the valleys and foothills and extending to the summit of the range; especially conspicuous and well grown on *Quercus lobata*, on whose rough bark it seems to attain its maximum development.

Dr. Zahlbruckner writes: "a *P. conspersa* distat thallo sorediis absito, reactionibus aliis, sporis microribus."

Parmelia soredica Nylander, Flora 68: 605. 1885.

14. PARMELIA CONSPERSA (Ehrh.) Acharius.

Thallus dilated, membranaceous, usually orbicular, but finally irregular and greatly expanded; marginally closely appressed, smooth, often polished, much and intricately divided or lobed; the lobes usually narrowed, often complicate and intricate; the central portion wrinkled or roughened, becoming isidiose, thickened or elevated, finally forming irregular heaps detached from the substratum; color varying from pale to dark yellowish- or gray-green; beneath pale to dark brown, or occasionally black, with short, scattered, concolorous fibrils, or even merely tuberculate; marginally darker, often lustrous. Apothecia numerous; margin incurved, crenate; disk chestnut.

Common on rocks throughout our range.

Like *Parmelia perforata* this species often turns a beautiful red or rose-purple color when pressed while wet, and occasionally one sees similarly discolored specimens on the rocks.

Lichen conspersus Ehrh. in Ach. Prodr. 118. 1798.
Parmelia conspersa Ach. Meth. Lich. 205. 1803; Lich. Univ. 486. 1810.

VIII. **Physcia** (DC.) Th. Fr.

Thallus usually foliaceous, stellate or orbicular, appressed, laciniately branched or lobed; more rarely fruticose or ascendant; beneath fibrillose or more seldom naked. Apothecia usually abundant, shield-shaped; the disk dark or blackish, often pruinose; spores bilocular, ellipsoid, brown.

This widely distributed genus is well represented in our territory, one or more species being present everywhere from sea level to the summit of the range.

Physcia Th. Fr. Lich. Arctoi 60. 1860.

KEY TO THE SPECIES.

a. Thallus fruticose, sterile, fringed with long black fibrils; on earth. 2. *leucomela*, 360.

aa. Thallus foliaceous.
  b. Thallus not appressed, lobes ascendant or sub-fruticose.
    c. Apothecia abundant; plant fuzzy, with long fibrils; maritime trees and shrubs.................................1. *erinacea*, 360.
    cc. Sterile; tips of ascendant lobes vaulted or hood-like. 11. *hispida*, 364.
  bb. Thallus appressed.
    d. Surface not pruinose.
      e. Color usually brown; thallus very thin, closely adherent, seemingly a part of the substratum..12. *adglutinata*, 365.
      ee. Color white or glaucous.
        f. Thallus sorediate; margin of lobes upturned, much cut. 10. *tribacia*, 364.
        ff. Thallus not sorediate; thickly sprinkled with small, white, sub-epidermal spots.
          g. Under surface white, with white fibrils. 8. *stellaris*, 363.
          gg. Under surface black with black hispid fibrils. 9. *aipolia*, 363.
    dd. Thallus more or less pruinose.
      h. Medullary layer and soredia more or less yellow or sulphur-color ....7. *muscigena*, 363.
      hh. Medullary layer white or greenish white.
        i. Apothecia with leafy or lobulate margin..6. *venusta*, 362.

ii. Apothecia without leafy or lobed margin.
  j. Thallus green, becoming brown or dingy.
    3. *pulverulenta*, 361.
  jj. Thallus not green or brown.
    k. Thallus silvery white; apothecial margin more or less sorediate ...4. *pulverulenta argyphæa*, 361.
    kk. Color bluish slate to dingy black.
      5. *pulverulenta isidiigera*, 362.

1. PHYSCIA ERINACEA (Ach.) Tuck.

Thallus small, matted or loosely tufted; naked, white or greenish white; beneath very white and often covered with a greenish powder; the ascendant lobes more or less flat, sinuous, and irregularly notched; contracting and dilating so as to be knobbed; marginally ciliate with very many long fibrils, so that the whole plant has a fuzzy appearance; cilia white, brown, or blackening; apothecia usually abundant, small, scattered; pedicellate; the disk convex, black or brownish-black; more or less bluish-white pruinose, becoming later naked; margin entire or minutely crenulate.

Confined to shrubs near the sea shore, occurring in both Lower and Upper California. Southward it is both abundant and luxuriant, but in our territory I have found only scanty specimens on dead or dying shrubs of *Artemisia californica*, growing on cliffs above the sea near Point San Pedro.

In the Stanford University herbarium are specimens from Santa Cruz Island, near Santa Barbara, and from Guadalupe Island, Lower California, collected by Mr. R. E. Snodgrass, of Stanford University. The best specimens seen were collected by Mr. LeRoy Abrams at Tia Juana, near San Diego.

Borrera erinacea Ach. Lich. Univ. 499. 1810.
Physcia erinacea Tuck. Proc. Am. Acad. 4: 388. 1860.

2. PHYSCIA LEUCOMELA (L.) Michaux.

Thallus fruticose, ascendant, elongated, forming diffuse clumps or mats; the lobes but little divided, narrow to linear, very much intertwined; margins with numerous stout, branched, black or dark fibrils; color above varying from greenish or pearly gray to pale dingy brown; under surface channelled, very white; white powdery; sterile.

Given by Tuckerman as growing on trees, but with us found as yet only on earth, agreeing thus with Leighton's description:

Found in some abundance in Pilarcitos Creek Cañon, at an altitude of 200–300 feet, growing on high clay banks and on earth in crevices of sandstone cliffs. A few scattered specimens were also found on clay banks beside the road over San Juan Hill, east of Monterey Bay, at an elevation perhaps not far from a thousand feet. This locality, however, is just beyond the southern boundary of our territory.

Lichen leucomelas L. Sp. Pl. ed. 2. 2: 1613. 1763.
Physcia leucomela Michaux, Fl. Bor. Am. 2: 306. 1803.

3. PHYSCIA PULVERULENTA (Schreb.) Nyl.

Thallus orbiculate or stellate; the numerous lobes usually long and broad, laciniate, crenate, their margins sometimes dissected, tips rounded; central lobes sometimes short, rounded, imbricate, with retuse tips; color greenish to brownish, the upper surface more or less white pruinose; beneath black, or marginally white, densely black fibrillose; medullary layer white or greenish white, apothecia wanting or imperfectly developed.

On stones in the foothills.

Lichen pulverulentus Schreber, Spicil. 128. 1771.
Physcia pulverulenta Nyl. Syn. Meth. Lich. 419. 1860.

4. PHYSCIA PULVERULENTA ARGYPHÆA Nyl.

Thallus orbicular or stellate, appressed; lobes discrete, narrow, elongate, many-cleft; their margins crenate or entire; usually upturned and confluently sorediate; thallus often becoming powdery sorediate or crustose at center, and now disappearing, leaving only the marginal lobes.

Varies from the type in having the thallus of a silvery white color; rarely darker or dingy. Medullary layer white or greenish white; apothecia rare; disk pruinose; margin thick, sorediate, entire or sometimes slightly dentate; spores 15 × 30 mic.

Common on trees in the foothills and mountains.

Physcia pulverulenta argyphæa Nyl.

5. PHYSCIA PULVERULENTA ISIDIIGERA Zahlbruckner, subsp. nov.

"Thallus adpressus, in laciniis marginalibus parcius in cesto thalli dense isidiis subcorallinis, brevibus, tenuibus, fuscis opacis que obsitus," Zahlbruckner in litt.

Thallus orbicular, marginally closely appressed and thin; becoming thick, heaped, and isidiose powdery or granular in central portion, all trace of lobes being lost; margin lobes short, crenate, imbricate; color brownish or dingy black; often bluish pruinose, the plant then of a pale, bluish slate-color; beneath black, the margin pale; covered with short black fibrils; medulla greenish white. Apothecia small; disk black, occasionally pruinose; margin thick, tumid, elevated, sorediate; spores 15–20 × 32–37.5 mic.

On trees, roofs and fences.

Very common in the lowlands about San Francisco Bay and back to the foothills, growing in great abundance on the shady side exposed to the moist bay winds. Very fine fruiting specimens were obtained from an old roof in Mayfield.

Type, No. 365, Stanford University Herbarium. Cotypes in Royal Botanical Museum, Vienna, in Hasse Herb., and Herre Herb. Type locality, old roof in Mayfield, Cal.

6. PHYSCIA VENUSTA (Ach.) Nylander.

Thallus expanded, orbicular, appressed; lobes many-cleft, narrow, laciniate or crenate, the tips usually rounded; inner lobes often marked with small tooth-like lobules; color varying from green through buff to tawny brown; gray pruinose at least on tips of lobes, but usually otherwise naked; beneath black and densely black fibrillose, usually pale at margin; medullary layer white. Apothecia pruinose, sessile; disk flat, black or reddish-black; often gray or bluish pruinose; margin thick, entire, fringed with small thalline lobules. Spores $\frac{15-17}{27-32}$ mic.

This species grows luxuriantly on oaks, principally *Quercus chrysolepis*, along the summit of the range at an altitude of 2200 feet and above.

Parmelia venusta Ach. Meth. Lich. 211. 1803.
Physcia venusta Nyl. Bull. Soc. Bot. Fr. 25 : 383, *pl. 25*. 1878.

7. PHYSCIA MUSCIGENA (Ach.) Nyl.

Thallus diffuse, spreading, irregular; the laciniate, numerous lobes short, narrow, distinct, often upturned at the tip; margins more or less sorediate or powdery with confluent, sulphur-colored soredia; surface often with isidiose or cephaloid outgrowths. Medullary layer usually greenish yellow or sulphur-colored; color brown, finally a very dark dull brown; rarely greenish; usually only tips of lobes pruinose; beneath white, becoming very dark; densely clothed with more or less hispid black fibrils. Apothecia rare, scattered; margin thick, becoming sorediate.

Common in the foothills on mossy sandstone and the trunks of oaks.

Parmelia muscigena Ach. Lich. Univ. 472. 1810.
Physcia muscigena Nyl. Syn. Meth. Lich. 1 : 418. 1860.

8. PHYSCIA STELLARIS (L.) Nylander.

Thallus smooth, appressed, stellate or irregular; lobes many-cleft, sinuate, very close together; thickly sprinkled with small white sub-epidermal spots; neither pruinose nor sorediate; color white; beneath white or pale, clothed more or less with simple white fibrils. Apothecia black, usually pruinose; margin entire.

On stones and twigs; not common.

Lichen stellaris Linn. Sp. Pl. 2 : 1144. 1753.
Physcia stellaris Nyl. Syn. Meth. Lich. 1 : 424. 1860.

9. PHYSCIA AIPOLIA (Ach.) Nylander.

Thallus orbicular, expanded, appressed; lobes much cleft, sinuous, separate and distinct, or coalescent and imbricate; very thickly sprinkled with small white sub-epidermal spots; surface smooth, without soredia; color white or bluish white; beneath dark or black, usually densely clothed with black hispid fibrils. Apothecia numerous, usually bluish pruinose; disk brownish black; margin thick, prominent, more or less crenate. Spores $\frac{5-10}{5-25}$ mic.

Common on twigs and trunks throughout our range. Particularly well developed on *Æsculus californica*, above 2000 feet. Abundant on rocks along the summit of the range.

Lichen aipolius Ach. Lichenogr. Suec. Prodr. 112. 1798.

Physcia aipolia Nyl. Flora, 53: 38. 1870.

10. PHYSCIA TRIBACIA (Ach.) Tuckerman.

Thallus more or less orbicular, usually rather small, much lobed; lobes short, intricately laciniate; their margins upturned, much dissected, granulate, becoming lined with confluent soredia; center of thallus sometimes converted to a granulate or serediate crust; color bluish white, gray, or ashy; beneath white, becoming buff centrally; sparingly covered with short, white fibrils. Apothecia not seen.

On trees and rocks.

Common in the lowlands and foothills, the best specimens on sandstone.

Lecanora tribacia Ach. Lich. Univ. 415. 1810.

Physcia tribacia Tuck. Lich. Am. Sept. No. 85; Syn. N. Am. Lich. 1: 75. 1882.

11. PHYSCIA HISPIDA (Schreb.) Tuckerman.

Thallus quite small; sub-stellate and appressed, or more commonly forming small, loose, diffuse clumps; the short ascendant lobes irregularly and deeply cleft, their tips inflated and vaulted, forming a very characteristic feature; margins of lobes beset with long, concolorous, or now darkening, fibrils; color white or bluish ashy gray; beneath white, with few short white fibrils. Sterile.

Frequent on trees and shrubs throughout. Common in the Stanford University arboretum on the stems of the giant cactus of Arizona, *Cereus giganteus*.

Lichen hispidus Schreber, Spicil. Fl. Lips. 126. 1771.

Physcia hispida Tuck., Obs. Lich. 397; Tuck. Syn. N. Am. Lich. 1: 75. 1882.

It seems to the author that this species should stand as *Physcia tenella* (Scop.) Nyl., when the synonymy should be as follows:

Lichen tenellus Scopoli, Flora Carn. ed. 2. 2: 394. 1772.
Physcia tenella Nyl. Flora 57: 306. 1874. Nom. Nud. Medd. Soc. Faun. Fl. Fenn. 13: 49. 1886.

12. PHYSCIA ADGLUTINATA (Floerk.) Nylander.

Thallus small, inconspicuous; very closely appressed so that it appears to be a part of the substratum; lobes thin, flat, coalescent; center of thallus often crustose; color "glaucescent becoming cinerescent and brown, pale and scarcely fibrillose beneath; apothecia small and very small; disk blackish brown; margin entire, scarcely ciliate." Tuckerman.

On trees and shrubs.

One olive-brown specimen of this obscure lichen was found by me on Black Mountain, at an altitude of 2500 feet, growing on the trunk of *Æsculus californica*. Unfortunately this specimen was afterward lost and at the time of writing no other specimens had been discovered.

Lecanora adglutinata Floerke, Deutsch. Lich. 4: 7. 1815.
Physcia adglutinata Nylander, Syn. Meth. Lich. 1: 428. 1860.

IX. **Gyrophora** Acharius.

Thallus horizontal, foliaceous, one-leaved to polyphyllous; when dry very brittle and hard, but leathery when moist; beneath naked or fibrillose; attached to the substratum at one point only, umbilicate. Apothecia innate or becoming prominent, rounded or angulate, the surface gyrose-plicate, black; spores of our species simple, ellipsoid, colorless.

Gyrophora Acharius, Meth. Lich. 110. 1803.

KEY TO THE SPECIES.

a. Thallus polyphyllous ....1. *polyphylla*, 365.
aa. Thallus one-leaved.
  b. Without fibrils beneath. ....2. *phæa*, 366.
  bb. Fibrils present beneath.................. ....3. *diabolica*, 366.

1. GYROPHORA POLYPHYLLA (L.) Turn. & Borr.

Thallus small to medium size, many-leaved, crinkled, cespitose; surface smooth, often polished; irregularly much lobed and dissected, the erectish lobules often slender with dilated and rounded tips; marginally crenate, dentate, unevenly cut, or erose; sometimes minutely and excessively dissected and crisped; color black or very dark brown; beneath naked, finely granulate, dull black. Sterile.

Not rare on the high sandstone cliffs at the head of Devils Cañon, at an altitude of 2300 feet, mingled with *Gyrophora diabolica*. Apparently not occurring elsewhere in the peninsula.

Lichen polyphyllus Linn. Sp. Pl. 2: 1150. 1753.

Gyrophora polyphylla Turn. & Borr. Lich. Brit. 214. 1839

2. GYROPHORA PHÆA (Tuck.).

Thallus small to medium, one-leaved or occasionally polyphyllous, smooth above; color brown, but varying from greenish or grayish to olive or dark tawny brown; under surface without fibrils, granular; usually darker brown or blackish, but sometimes paler. Apothecia numerous, black; at first innate but finally prominent; angular or rounded; plicate; spores simple, colorless.

On bare, exposed, sun-blistered rocks; most frequently on sandstone but also on igneous rocks. According to Tuckerman found only between 1000 and 3000 feet altitude, but really extending much above and below those limits. Occurring from Searsville ridge, at an elevation of about 350 feet, to the summit of Loma Prieta, 3788 feet. In the Mt. Hamilton Range across the Santa Clara Valley from the Santa Cruz Mountains, it occurs in Alum Rock Park near San Jose at about 200 feet above sea level. Usually abundant wherever found. My largest specimens have a diameter of somewhat more than two inches.

Umbilicaria phæa Tuck. Lich. Calif. 115. 1866; Tuck. Syn. N. Am. Lich. 1: 86. 1882.

3. GYROPHORA DIABOLICA Zahlbruckner, sp. nov.

Thallus small to medium, one-leaved becoming many-leaved and complicate; more or less orbicular, the edges torn or irregular; coriaceous, rigid, usually smooth and polished; color a very dark rich brown, becoming olive when moist: beneath black, granulate, more or less covered with short, dense, black fibrils. Fertile plants infrequent; apothecia at first innate and very small, but finally large, rounded or irregularly oblong, prominent and dome-like, reaching a diameter of 8 mm.; beautifully gyrose-plicate, black; spores simple, colorless, short ellipsoid, $\frac{7\frac{1}{2} \text{ to } 13\frac{1}{2}}{5 \text{ to } 7}$ mic.

"differt a *G. angulata* apotheciis omnino aliis, a *G. muhlenbergii*, quacum forma apotheciorum convenit, thallo minore, subtus atrofibrillosus, non reticulato." A. Zahlbruckner *in litt.*

Abundant on high sandstone cliffs in Devils Cañon, at an altitude of 2000–2300 feet; mingled with *G. phæa* and *G. polyphylla* but from its greater size and abundance forming the dominant tone of the rock lichen flora. As yet not found elsewhere in the range.

Type, No. 682, Stanford Univ. Herbarium. Type locality, Devils Cañon, Santa Cruz peninsula, Cal. Cotypes in Herb. Hasse, Herb. Herre and Royal Botanical Museum in Vienna, Austria. Coll. A. C. Herre, July 28, 1905.

X. **Sticta** (Schreb.) Fr.

Thallus foliaceous, leaf-like, the fronds usually wide-lobed, rounded or elongate. Color of our species various; green, brown, russet, or black; under side pale, villous or fleecy, dotted with cyphels or pale bare spots. Apothecia shield-like, marginal or scattered, sessile, the disk red-brown and darkening or black. Spores elongated, slender, 2- to 4-locular, colorless.

Growing on trees, dead wood, rocks, and earth.

For the present the arrangement of Tuckerman has been followed, though the genus as given by him probably includes at least three good genera, if not four.

Sticta Schreber in L. Gen. Pl. ed. 8. 2: 768. 1791.
Sticta Fries, Lich. Europ. Reform. 49, 348. 1831.

KEY TO THE SPECIES.

a. Under side of thallus without cyphels; marked by naked pale areas or spots.
  b. Spots large, convex; between, more or less brown-veined. 1. *pulmonaria*, 368.
  bb. Spots small, white or pale, flat or sunken, scattered through the dense, dark nap........................5. *scrobiculata*, 369.

aa. Under surface with cyphels.
  c. Not sorediate; thallus black, always sterile....2. *fuliginosa*, 368
  cc. More or less sorediate.
    d. Thallus smooth, marginally sorediate; always sterile. 3. *limbata*, 368.
    dd. Thallus lacunose-reticulate; apothecia usually abundant. 4. *anthraspis*, 369.

1. STICTA PULMONARIA (L.) Acharius.

Thallus leathery, medium to very large, irregularly and loosely lobed; the surface reticulate and deeply pitted; lobes narrow, deeply and sinuously crenate; the margins and reticulations often sorediate or isidiose; color varying from bright green to olivaceous and yellowish brown; under surface pale or dark brown villose veined, between large, pale, naked, bullate spots. Apothecia infrequent, marginal, small; disk red-brown.

Common on trunks of trees in the mountains above 1500 feet; reaching its best development in the redwoods at about 2000 feet altitude, the immense lax lobes sometimes having a spread of nearly two feet.

Occurring also on shaded mossy sandstone in Devils Cañon, at 2300 feet.

Lichen pulmonarius L. Fl. Suec. 1087. 1755.
Sticta pulmonaria Ach. Lich. Univ. 449. 1810; nom. emend., given as *S. pulmonacea*.

2. STICTA FULIGINOSA (Dicks.) Acharius.

Thallus leathery, more or less round-lobed: lobes short, wrinkled and pitted, the margin entire, sinuous or somewhat crenate; color a dark brownish or lurid gray, this obscured by the dense covering of black isidia, so that the surface appears black; beneath pale brown, tomentose; more or less sprinkled with white, concave cyphels. Sterile.

On rocks, trees, dead wood, old fences, moss, and earth.

Common at all elevations above 100 feet.

Lichen fuliginosus Dickson, Brit. Crypt. 1: 13. 1785.
Sticta fuliginosa Ach. Meth. Lich. 281. 1803.

3. STICTA LIMBATA (Sm.) Acharius.

Thallus small, usually one-leaved; lobes smooth, rounded, broad, the margin crenate or sinuous; confluent gray soredia abundant along or near the margin; color in the field usually a glaucous green: herbarium specimens vary from bluish or greenish drab or gray to dull rufous brown; beneath covered with a pale brown fleece which becomes darker centrally; white concave cyphels rather sparingly present. Sterile.

On tree trunks, growing with other Stictas.

Not uncommon along the summit of the range at an altitude of 2400 feet and above.

Lichen limbatus Smith, in Eng. Bot. 16: *pl. 1104.* 1802.
Sticta limbata Ach. Meth. Lich. 280. 1803.

4. STICTA ANTHRASPIS Acharius.

Thallus medium to large, rounded or irregular, usually conspicuously pitted and reticulate; texture leathery or parchment-like; short and wide-lobed, margin sinuous, rounded and crenate, or often more narrowly and deeply cut, even becoming lacerate; ridges of surface often covered with confluent gray soredia; color usually brown, but varying from green to russet or chocolate; sometimes darkening; beneath covered with a pale dense fleece, becoming darker toward the center or sometimes entirely dark or dingy black; thickly sprinkled with small white convex cyphels. Apothecia scattered, becoming very abundant; disk red-brown, sometimes dark or black; flat, finally convex and excluding the prominent, entire or denticulate margin.

On trees, roots and occasional on old fences; rarely on earth.

Very abundant in the mountains at all elevations and extending downward in the foothills to about 200 feet. Usually sterile at lower elevations but luxuriant and fruitful in San Mateo Cañon at not more than 200 feet.

Often attaining a diameter of 10 or 12 inches, being next in size to *Sticta pulmonaria*.

Sticta anthraspis Ach. Meth. Lich. 280. 1803.

5. STICTA SCROBICULATA (Scop.) Acharius.

Thallus medium, round or sub-orbicular, leathery, short-lobed; surface more or less pitted or wrinkled; thickly sprinkled with gray soredia; lobes rounded, imbricate, but little incised, more or less crenate; color of herbarium specimens dull yellowish green or gray. In the field often a dark liver-green, beneath densely villous, buff to dark brown or dingy black; more or less interspersed with naked white or pale spots. Sterile.

On trees and rocks.

Common in the mountains above 1500 feet. Also very abundant on a sandstone cliff in Pilarcitos Creek Cañon, two miles from the Pacific Ocean, at an altitude from 200 to 300 feet.

Lichen scrobiculatus Scopoli, Fl. Carn. 384. 1772.
Sticta scrobiculata Ach. Lich. Univ. 453. 1810.

XI. **Nephromium** Nylander.

Thallus foliaceous, membranaceous, expanded; our species of small to medium size; naked, or clothed with a nap beneath, but not veined.

Apothecia reddish brown, innate on the under side of the more or less extended and narrowed lobes: usually exposed to view by the curling of the tips of the lobes; spores dark, quadrilocular, subfusiform.

Nephromium Nylander, Mém. Soc. Cherb. 5: 101. 1857 (nota);
Nylander, Syn. Meth. Lich. 1: 318. 1860.

KEY TO THE SPECIES

a. Under side of thallus with white tubercles.
1. *tomentosum rameum*, 370.
aa. Under side not white tuberculate.
  b. Under side tomentose; medulla white........2. *helveticum*, 371.
  bb. Under side smooth; medulla yellow.......3. *lusitanicum*, 371.

1. NEPHROMIUM TOMENTOSUM RAMEUM Nyl.

Thallus expanded, membranaceous, medium to large; lobes rounded, crenate, tomentose at the margin; becoming elevated and finally imbricate and complicate; beneath covered with a pale fleecy nap in which are many small white or yellowish tubercles, these larger and more numerous on basal portion of lobes; color a dusky velvety brown usually, but varying from greenish brown to almost chestnut. Apothecia large, numerous, reddish brown.

On trees and shrubs; commonest on *Rhus diversiloba*.

Apparently confined to damp undergrowth in oak woods about the summit of the range. Abundant on Black Mountain, Page Mill road, at 2000 feet.

Nephromium tomentosum subspecies *rameum*, Nyl. Norrl. Med. Sällsk. Faun. et Flor. Fenn. 1: 18. 1876.

Nephroma rameum Schaerer, Enumerat. Crit. 18, *pl. 2, f. 3*. 1850.

2. NEPHROMIUM HELVETICUM Acharius.

Thallus small or medium, expanded, intricately and sinuously complicate-lobed; lobes rounded, more or less crisped, their margins crenate, typically fringed with small or minute tooth-like lobules; surface smooth or minutely granular, but occasionally sprinkled with pustules or lobulate outgrowths; sometimes deeply pitted; medullary layer white; beneath pale brown to dusky, covered with a dense concolorous nap; color brown, of varying shades. Apothecia abundant, very dark red.

On trees and shrubs in the mountains, above 1700 feet.

Apparently confined to dense damp woods near the summit of the range; widely distributed but not very abundant at any one locality.

Nephroma helvetica Ach. Lich. Univ. 523. 1810.

Nephroma helveticum Tuck. Syn. N. Am. Lich. 1: 104. 1882.

3. NEPHROMIUM LUSITANICUM (Schaer.) Nyl.

Thallus expanded, rounded; of medium size but becoming rather large by the coalescence of adjacent plants; deeply and sinuately imbricate-lobed; lobes crenate at tip, their margins sometimes minutely crenate or notched, when they simulate the denticulate margins of *Nephromium helveticum*. Surface smooth, becoming more or less wrinkled; color varying from drab and pale brown to dark chestnut; beneath smooth, more or less wrinkled; pale brown, becoming dusky and finally black: medullary layer yellow. Apothecia numerous, medium to large.

Very abundant on mossy sandstone and trunks of oaks in Devils Cañon, at an altitude of 2300 feet. Not found as yet elsewhere, but no doubt occurring at the head of similar deep cañons rising from the heavy redwood forests of the Pescadero and other coast streams.

Nephroma lusitanicum Schaerer, Enum. Crit. 323. 1850.
Nephromium lusitanicum Nyl. Flora 38. 1870.

XII. **Peltigera** Willd.

Thallus frondose, lobate; beneath veined, villous or fibrillose.

Apothecia adnate on tips of the more or less extended and narrowed fertile lobes; spores elongated, slender, 4- to 8-locular, colorless.

Common throughout, on earth, moss, rocks, and trunks.

Peltigera Willd. Fl. Berol. 47. 1787.

KEY TO THE SPECIES.

a. Thallus more or less marginally sorediate............1. *scutata*, 372.
aa. Thallus never sorediate.
  b. Tips of lobes not tomentose; thallus thick, rather rigid. 2. *rufescens*, 373.
  bb. Tips of lobes more or less very minutely tomentose.
    c. Thallus medium to large, thin......................3. *canina*, 373.
    cc. Very thin and papery, expanded. 4. *canina membranacea*, 374.

1. PELTIGERA SCUTATA (Dicks.) Leighton.

Thallus comparatively thick; much and irregularly lobed; lobes undulately crenate, their edges confluently gray sorediate; surface smooth, occasionally sorediate; the lobes sometimes finally converted into a powdery sorediate heap, losing all semblance of the original thalline form except marginally; color greenish ashy or gray, or more seldom reddish brown; beneath white, with broad, tomentose, anastomosing, brown veins; these dark brown or blackening centrally and finally coalescing so as to obscure the under surface, which appears only as small white or pale brown spots in the dark area. More or less fibrillose near the margins. Apothecia dark reddish brown to black.

On sandstone, tree trunks, and earth, among moss.

Common at all altitudes above 300 feet. Reaching its greatest vegetative development on perpendicular mossy sandstone cliffs, where it forms extensive mats, but is usually sterile.

Occasionally abundantly fertile, especially on trees, but as a rule apothecia are rare and scattered.

Lichen scutatus Dickson, Pl. Crypt. Brit. 3: 18. 1793, excl. syn.

Peltigera scutata Leighton, Lich. Fl. Gt. Brit. ed. 1. 210. 1871.

2. PELTIGERA RUFESCENS (Neck.) Hoffm.

Thallus small or medium, rather rigid and thick, smooth, rounded, irregularly laciniate; lobes more or less imbricate, becoming narrowed, crowded, and somewhat crisped marginally; color varying from pale greenish gray to reddish, finally russet or dark brown: pale brown beneath, reticulate with thick brown veins; these thinly sprinkled with coarse brown fibrils. Apothecia often clustered; comparatively large; terminal on long narrow lobes; disk reddish brown and darkening.

On earth, moss, and rocks, in the foothills.

Lichen rufescens Necker, Meth. Musc. 79. 1771.

Peltigera rufescens Hoffm. Deutsch. Fl. 2: 107. 1795.

3. PELTIGERA CANINA (L.) Hoffm.

Thallus thin, orbicular, becoming expanded, irregular, and very large; lobes large, broad, imbricate, intricately cut: tips rounded or often more pointed, more or less deeply crenate. Surface smooth, terminal margin sometimes with minute pubescence, not visible except with a powerful magnifier. Apothecia marginal, numerous; circular, becoming elongate; disk red-brown; color greenish gray or drab, varying to reddish or brown. Beneath very pale, netted with pale, prominent veins of the same color, these sometimes darkening centrally; long conspicuous concolorous or darkening fibrils present.

Common on earth and moss throughout.

Lichen caninus L. Syst. Nat. ed. 10. 1342. 1759; Fl. Suec. 1109. 1755.

Peltigera canina Hoffm. Deutsch. Fl. 2: 106. 1795.

4. PELTIGERA CANINA MEMBRANACEA (Ach.) Nyl.

Thallus very thin and papery, becoming greatly expanded, the surface smooth and more or less pitted and furrowed. Lobes large, dilated, rounded, irregularly crenate and laciniate, more or less imbricate, often forming mats several layers in thickness; tips of lobes often visibly tomentose; color and under surface as in typical form. Apothecia numerous, marginal or terminal on somewhat narrowed and extended lobules.

Occurring throughout with the type on mossy tree trunks and on earth and stones.

Peltidea canina membranacea Ach. Lich. Univ. 518. 1810.
Peltigera canina membranacea Nyl. Syn. Meth. Lich. 1: 324. 1860.

XIII. **Endocarpiscum** Nylander.

Thallus quite small, one-leaved, umbilicate. Apothecia immersed, indicated only by an ostiole, or superficial, lecanorine. Spores numerous, very minute, simple, colorless.

Endocarpiscum Nylander, Flora 47: 487. 1864.

1. ENDOCARPISCUM GUEPINI (Moug.) Nyl.

Thallus small to very small, one-leaved, umbilicate, appressed, rounded, scattered or crowded and imbricate; the sinuous, crenate, upturned margin bluish sorediate; color brownish olive to gray; beneath naked, smooth, wrinkled, flesh-color, brown, or even blackening. Apothecia deeply imbedded in tiny pits, invisible to the naked eye; sometimes becoming superficial, lecanorine, black. Spores very small, numerous, simple, colorless.

Abundant in the foothills at moderate elevations and on cliffs above the ocean. An inconspicuous plant easily overlooked; readily recognized by the blue sorediate margin.

For the present I follow Tuckerman's classification of this lichen; Dr. Zahlbruckner places it in the genus *Heppia*.

Endocarpon guepini Moug. Fr. Lich. Eur. 410. 1831.
Endocarpiscum guepini Nyl. Flora 47: 487. 1864.

XIV. **Ephebe** Fries.

Thallus fruticulose, branched, composed mainly of the alga *Sirosiphon pulvinatus* associated with a fungus, the form and habit of the plant being due mainly to the alga; color black; apothecia immersed or superficial and globose; spores ellipsoid or colorless. On rocks.

Ephebe Fries, Syst. Orb. Veg. 256. 1825.

1. EPHEBE PUBESCENS (L.) Fries.

Thallus small, erect, tufted, minutely shrub-like, compact, much branched, sooty black. Alga *Sirosiphon*. Sterile.

Abundant on perpendicular sandstone rocks at several different places in the Searsville ridge, at an altitude of about 400 feet. As yet not seen elsewhere.

A very remarkable form unlike any other lichen of our flora.

Lichen pubescens L. Sp. Pl. 2: 1155. 1753.
Ephebe pubescens Fries, Fl. Scan. 294. 1835.

XV. **Collema** Wigg.

Thallus foliaceous, very small to medium size, very dark green, or blackening; cortical layer not present or indistinct; apothecia scattered or crowded, usually numerous, very small to medium size; spores ellipsoid, spindle-shaped or needle-shaped; 4-locular, plurilocular, and muriform; colorless.

On trees, earth, and rocks.

Collema Wigg.; Weber, Prim. Fl. Hols. 89. 1780.

KEY TO THE SPECIES.

a. Confined to trees.
  b. Surface with anastomosing ridges covered by black granules. 1. *aggregatum*, 376.
  bb. Surface radiately wrinkled and pustulate.
    c. Surface, smooth, naked .... 2. *vespertilio*, 376.
    cc. Surface isidiose-pulverulent .... 3. *nigrescens*, 376.
aa. Confined to earth and rocks.
  d. Thallus not squamulose or crustaceous.
    e. Very gelatinous; on earth in damp places.
      f. Thallus rather large, smooth, more or less pustulate and wrinkled; apothecia small .... 4. *pulposum*, 377.

ff. Thallus usually forming only a border to the large, crowded, imbedded apothecia........................5. *limosum*, 377.

ee. On limestone rocks.

g. Thallus thick, undulate, plicate..............6. *plicatile*, 378

dd. Thallus minute, squamulose or crustose...7. *cristatellum*, 378.

1. COLLEMA AGGREGATUM Nyl.

Thallus small or medium size, circular, irregularly lobed, with crenate margin; marked by thick, rough, anastomosing ridges densely covered by black granules; more or less fenestrate; color dark green or black; beneath pale, smooth, much wrinkled and pitted; apothecia numerous, mostly on the ridges; disk from concave becoming flat or even convex; reddish or darkening; margin entire; spores fusiform, long, plurilocular, $\frac{45-75}{4-5}$ mic.

On trees. Not rare in the foothills.

Collema aggregatum Nyl. Mem. Soc. Sc. Nat. Cherb. 2: 318. 1854.

2. COLLEMA VESPERTILIO (Lightf.) Wainio.

Thallus of medium size, orbicular, thin, closely appressed; lobes rounded, with entire or crenate margin; surface naked, smooth, radiately wrinkled and thickly pustulate; color yellow-green, very dark green, and black; beneath paler or concolorous, lacunose or pitted; apothecia small, usually very numerous and crowded; disk reddish or blackening: plane, becoming convex; spores needle-shaped or fusiform, long, plurilocular, $\frac{47\frac{1}{2}-55}{5}$ mic.

On trees and perhaps occasional on rocks. Common in the foothills at moderate elevations. Our most abundant *Collema*.

Lichen vespertilio Lightfoot, Flora Scotica 2: 840. 1777.

Collema vespertilio Wainio, Act. Soc. Faun. Fl. Fenn. 7: 235. 1890.

3. COLLEMA NIGRESCENS (Huds.) Wainio.

Thallus medium size, more or less orbiculate, thin, marginally closely appressed, the rounded lobes with margins more or less undulate or crenate; surface radiately ridged and pustulate, finally densely isidiose pulverulent; color very dark green or blackish green; beneath concolorous or paler, lacunose, pitted or fenestrate. Apothecia usually infrequent and scattered, rarely numerous, small to medium; the disk dark red-brown; the entire margin rather thick, finally excluded; often isidiose, when it is tuberculate-radiate or toothed.

On trees in the foothills. Fairly common.

Lichen nigrescens Hudson, Flora Anglica 450. 1762.

Collema nigrescens Wainio, Act. Soc. Faun. Fl. Fenn. 7: 235 1890.

4. COLLEMA PULPOSUM (Bernh.) Ach.

Thallus thin, small to medium size, orbicular or irregular, closely appressed, usually depressed or concave centrally; very soft and gelatinous when moist; lobes rounded, sometimes imbricate, margin varying from entire and sinuous to crenate and slightly laciniate or even denticulate; surface smooth, more or less pustulate and wrinkled; sometimes beset with tiny erect lobules; color dark green or black; sometimes brownish; beneath paler, smooth, wrinkled. Apothecia small, numerous; disk flat or concave, reddish, with paler entire margin; spores ovoid, from 4-locular becoming sub-muriform.

On earth on damp hillsides, forming rather extensive patches among mosses. Not rare in the foothills at an elevation of about 1000 feet.

Lichen pulposus Bernhardi in Schrader's Journ. Bot. 1: 7. *pl. 1, f. 1.* 1799.

Collema pulposum Ach. Lich. Univ. 632. 1810.

5. COLLEMA LIMOSUM Ach.

Thallus thin, small to medium, irregular or scattered, very closely appressed; margin irregularly crenate or dentate-lobulate; surface smooth, or here and there beset with small ascendant lobules; color black or dark green. Thallus mostly disappearing and becoming merely a net-work or margin about the numerous large, imbedded apothecia; disk mostly flat, reddish or blackening; spores usually in fours in the thekes, ellipsoid, muriform-plurilocular.

On a wet clay bank beside a spring a mile above Wright's

Station; altitude about 1000 feet. Probably occurring in similar situations throughout the mountains.

Lichen limosus Ach. Lich. Suec. Prodr. 126. 1798 (excl. syn. *Collema graniformis* Hoffman).

Collema limosum Ach. Lich. Univ. 629. 1810.

According to Crombie, Brit. Lich. 1: 47. 1894, *Collema limosum* is a synonym of *Collema glaucescens* Hoffman, Deutsches Flora 2: 100. 1795. If this is correct the name proposed by Acharius must be discarded.

6. COLLEMA PLICATILE Ach.

Thallus, small, orbicular, thick, laciniate; divisions distinct, separate, or disappearing centrally leaving only the marginal lobes; these rugose, undulate-plicate, compact, more or less ascendant; surface sometimes covered with small erect granules or lobules; color dingy brownish green or black. Apothecia small to medium, numerous, concave or usually plane; disk reddish or more often blackening, the margin entire or flexuous; spores ovoid ellipsoid, quadrilocular, 8 × 30, 7½ × 32½, and 7½ × 35 mic.

On limestone rocks near the summit of Black Mountain, altitude 2700 feet, and at New Almaden, at about 1200 feet. Rare.

Conspicuously different in habit from any other *Collema* in our flora.

Lichen plicatilis Ach. Nov. Att. Acad. Sci. Stockh. 16: 11, *pl. 1, f. 2.* 1795.

Collema plicatile Ach. Lich. Univ. 635. 1810.

7. COLLEMA CHRISTATELLUM Tuckerman.

Thallus scattered, microscopic, forming an indeterminate crustaceous or squamulose crust; lobes minute, ascendant, with more or less dissected and crenate or dentate edges, or reduced to tiny erect lobules; color greenish or brownish black. Apothecia medium size, concave; disk concolorous or reddish; margin entire.

On clay and crumbling rock on a steep slope in Hidden Villa Cañon, elevation 800 feet. Probably occurring throughout in similar situations but too readily overlooked.

Determination by Dr. Hasse: through an oversight not submitted to Dr. Zahlbruckner.

Collema cristatellum Tuck. Lich. Calif. 29. 1866; Tuck, Syn. N. Am. Lich. 1: 152. 1882.

XVI. **Leptogium** Gray.

Thallus foliaceous or rarely fruticulose, with a distinct cortical layer; lead-colored, brown, dark green, or black. Apothecia scattered or crowded, usually numerous, small; spores bilocular, to plurilocular or muriform-multilocular, ovoid or ellipsoid, colorless.

Our species not well known as yet; only those which have been positively identified are herein described, although at least two or three more species are represented in our flora.

Leptogium Gray, Nat. Arr. 1: 395. 1821.

KEY TO THE SPECIES.

a. On earth, moss or rocks.
  b. More or less white fleecy beneath, margin minutely white ciliate. 1. *albociliatum*, 380.
  bb. Without nap or fibrils beneath.
    c. Thallus very small, rather entire...............2. *scotinum*, 380.
    cc. Thallus medium size to large.
      d. Color red-brown, chestnut or plumbeous; lobes narrowed, corniculate tipped ....5. *palmatum*, 381.
      dd. Color black.
        e. Erectish, crenate, narrowed, complicate. 3. *californicum*, 381.
        ee. Flat, expanded, suborbiculate. 4. *californicum platynum*, 381.
aa. On trees.
  f. Dark green to black: usually smooth beneath; thallus fenestrate wrinkled, with isiodose granulate or isidiose lobulate ridges. 6. *chloromelum stellans*, 382.
  ff. Lead-color to blackish green.
    g. Beneath fleecy, with long white or brown fibrils. 7. *saturninum*, 382.
    gg. Beneath covered with minute velvety pubescence. 8. *myochroum tomentosum*, 383.

1. LEPTOGIUM ALBOCILIATUM Desmaz.

Thallus small to medium size, rounded, by coalescence forming extensive indeterminate mats; lobes imbricate, deeply and sinuately laciniate, their tips rounded or pointed; margin in folds or crisped, up-turned, crenate, lacerate, or denticulate; surface smooth, centrally often granulate or with small erect lobules; color greenish black; the margin ciliate with minute white bristles; under surface paler; marginally with a conspicuous white fleece; this longer, shaggy, and brown within, rarely disappearing. Apothecia numerous, becoming crowded when present; small to medium size, sessile; disk reddish, plane or convex; margin pale, entire, finally disappearing; often bristly with minute white cilia similar to those on margin of thallus. Spores bilocular.

Found throughout on rocks and earth among mosses.

Fruiting abundantly at 3000 feet altitude on Castle Rock Ridge and in Devils Cañon at 2300 feet; still luxuriant in growth as low as 2000 feet. Extending downward to 150 feet in the foothills, but there reduced and sterile.

Fruiting specimens collected too late to be submitted to Dr. Zahlbruckner.

Leptogium albocilatum Desmazieres, Ann. Sci. Nat. IV. 4: 132. 1855.

2. LEPTOGIUM SCOTINUM (Ach.) Fries.

Thallus small, suborbicular or effuse, appressed, with upturned edges; lobes rounded, more or less complicate; margin entire, crenate, or somewhat laciniate: greenish lead-color to brown. Apothecia numerous and comparatively large, reddish brown; margin entire, paler; spores $\frac{24-40}{10-16}$ mic., muriform-multilocular.

On earth, among mosses.

A few specimens collected on a high clay bank on Black Mt., at an altitude of 900 feet. Should be looked for in similar situations throughout. From its small size too readily overlooked.

Lichen scotinus Ach. Lichenogr. Suec. Prodr. 128. 1798.
Collema scotinum Ach. Lich. Univ. 651. 1810.
Leptogium scotinum Fries, Sum. Veg. 122. 1846.

3. LEPTOGIUM CALIFORNICUM Tuck.

Thallus medium size, indeterminate, irregularly and narrowly laciniate and cut-lobed; the margins erect, crinkled or much and intricately folded, more or less crenate, serrate, or dentate-lobulate, or sometimes merely granulate. Thallus occasionally much reduced, the erect, very narrow much dissected lobes then densely crowded; color black or dark brown; margin often lustrous as if oiled or varnished. Apothecia infrequent, small, red-brown, the paler margin elevated, entire or more or less dentate.

Occurring throughout, forming large coal-black mats on mossy sandstone ledges at moderate elevations in the foothills; reduced forms occurring in rock crevices as low as 150 feet.

Leptogium californicum Tuck. Syn. N. Am. Lich. 1: 159. 1882.

4. LEPTOGIUM CALIFORNICUM PLATYNUM Tuck.

Thallus medium to large, orbicular, or indeterminate through fusion of adjacent plants; appressed; lobes irregular, elongate and expanded, imbricate, with crenate or dentate margin; surface finely striate or wrinkled, more or less pustulate, occasionally minutely lobulate; beneath paler, finely wrinkled; color black or greenish black; rarely brownish black. Apothecia very numerous, minute, reddish brown, the prominent entire margin paler; spores 48 × 16 mic., muriform multilocular.

On earth, roots, and rocks, in damp situations. Abundant on Castle Rock Ridge from 1500 to 3000 feet elevation. As yet not seen elsewhere.

A very distinct and handsome lichen.

Leptogium californicum platynum Tuck. Syn. N. Am. Lich. 1: 159. 1882.

5. LEPTOGIUM PALMATUM (Huds.) Mont.

Thallus medium to large, more or less tufted, very irregular, deeply laciniate; lobes more or less convolute, with crenate margin, the 2–4 corniculate tips erect, narrow, tubular, pointed or blunt; surface of thallus finely wrinkled and pitted; beneath paler, wrinkled; color usually reddish brown to chestnut;

sometimes greenish lead-color. Apothecia scattered, becoming very numerous and crowded, concolorous or red-brown; the paler elevated margin entire. Spores $\frac{30\text{-}40}{15}$ mic., muriform-multilocular.

On earth, mosses, and rocks; often occurring in very extensive tufted patches. Abundant.

Lichen palmatus Hudson, Fl. Ang. ed. 2. 536. 1778.

Leptogium palmatum Montagne, Pl. Cell. Voy. Pol. Sud, 128. 1845.

6. LEPTOGIUM CHLOROMELUM STELLANS Tuck.

Thallus orbicular, becoming indeterminate, medium to very large, more or less fenestrate, laciniate; lobes usually narrow, irregular, more or less imbricate or coalescing; surface striate, wrinkled, and ridged, the ridges densely covered with black isidiose granules, or by cristate-lacerate isidiose lobules; color dark green, plumbeous, or black; beneath paler, wrinkled; rarely a very minute down sparingly present.

Sterile.

On trees. Common; reaching its maximum development at an altitude of from 500 to 800 feet, the loosely connected thallus often 4 or 5 inches in diameter.

Lichen chloromelos Swartz, Fl. Ind. Occident. 3: 1892. 1806.

Leptogium chloromelum Nyl. Syn. Meth. Lich. 1: 128. 1860.

Leptogium chloromelum stellans Tuck. Syn. N. Am. Lich. 1: 163. 1882.

7. LEPTOGIUM SATURNINUM (Smith) Schaer.

Thallus large, orbicular, one-leaved or polyphyllous and imbricate; the long, irregular, sinuate lobes rounded at the tips; their margins upturned, more or less convolute and elevated; sometimes with finely laciniate edges, margined with isidiose granules; upper surface varying from smooth to granular or finally densely isidiose granulate; color plumbeous to greenish black, with usually a more or less evident metallic rufous or bronze lustre; granules, when present, brownish black; beneath paler, finely wrinkled; covered with a white or brown fleece, this becoming interruptedly long and shaggy. Sterile.

On trunk of trees; abundant throughout.

Lichen saturninum Smith, Trans. Linn. Soc. 1: 84. 1791.
Leptogium saturninum Schaerer, Lich. Helvet. Spicil. 534. 1840.

8. LEPTOGIUM MYOCHROUM TOMENTOSUM (Schaer.) Tuck.

Thallus orbicular, flattish, much thinner than *L. saturninum;* lobes large, round, somewhat plaited. Color greenish black with very small black granules more or less thickly sprinkled over the surface; beneath pale, smooth, very minutely velvety pubescent. Sterile.

On trees. Rare. A very few specimens collected on Black Mountain, at an elevation of 2200 feet.

Identification by Dr. Hasse and the author; no specimens available to submit to Dr. Zahlbruckner.

Leptogium tomentosum Schaerer.
Leptogium myochroum tomentosum Tuck. Syn. N. Am. Lich. 1: 166. 1882.

XVII. **Placodium** (DC.) Naeg. & Hepp.

Thallus typically crustaceous and lobate at the circumference, or uniform; very rarely suffruticose, as in the species described below; color usually yellow or orange.

Apothecia generally scattered, but in the following species terminal; the disk usually yellow or orange. Spores ellipsoid, polar-bilocular in the present species as is typical of the genus, simple, colorless.

Placodium DeCandolle, Fl. Fr. 2: 377. 1805; Naegeli & Hepp in Hepp, Abb. u. Beschr. d. Spor. d. Flecht. Eur. pl. 2, et passim. 1853.

1. PLACODIUM CORALLOIDES Tuck.

Thallus slender, solid, cartilagineous, decumbent, forming orbiculate, eventually indeterminate patches; branches terete, nodulose, blunt, sub-dichotomously divided, much intertangled; color bright yellow or orange, finally dark orange; underneath and basally grayish or blackening. Apothecia small to medium, lateral or terminal, sub-pedicellate: the rough, dark-orange disk somewhat concave, becoming finally convex and excluding the entire, thin, elevated margin. "Spores oblong, the sporoblasts approximate, the isthmus deficient, $\frac{10-15}{5-6}$ mic. The biatorine apothecia bordered more or less, or coronate, with the finally powdery nodules of the thallus; 1–2 mm. wide."

The above description but little altered from Tuckerman's excellent diagnosis.

Very abundant on sandstone ledges from Pescadero Point southward along the coast to Pigeon Point. It grows usually within a few feet of the water, barely above ordinary high tide, and must be submerged at every storm or unusual tide.

Identification by the author.

Placodium coralloides Tuck. Proc. Am. Acad. 6: 287. 1864; Syn. N. Am. Lich. 1: 169. 1882.

XVIII. **Lecanora** (Ach.) Tuck.

Thallus typically crustaceous and uniform; in some species lobed and sub-foliaceous and in a few Californian species fruticose. Apothecia (in the present species) sub-pedicellate, terminal or sub-terminal; the spores simple, colorless, ellipsoid.

A strict interpretation of this genus will undoubtedly exclude certain sections of the group as interpreted by Tuckerman, *e. g.*, *Acarospora*.

Lecanora Ach. Lich. Univ. 77. 1810; in part.

Lecanora Tuck. Gen. Lich. 110. 1872; Syn. N. Am. Lich. 1: 181. 1882.

KEY TO THE SPECIES.

a. Species fruticose, stout, short, erect; on rocks.
  b. Apothecia abundant, terminal or sub-terminal.
    c. Disk yellowish, tawny, dusky, or black......1. *bolanderi*, 384.
    cc. Disk pale yellowish to tawny red...........2. *thamnitis*, 385.
  bb. Sterile. (Apothecia lateral when present, with pale-brick-colored disk)................................3. *phryganitis*, 385.

1. LECANORA BOLANDERI Tuck.

Thallus fruticose, short, rigid, dichotomously divided, forming dense clumps ultimately; branches terete, erect, blunt; color a yellowish green. Apothecia terminal, medium size, becoming large; disk concolorous or decidedly yellowish, sometimes tawny, dusky, or blackening; margin swollen, entire or more or less crenate or denticulate. Spores $\frac{12\frac{1}{2}-14}{5-6}$ mic.

On granite cliffs 250–300 feet above the sea, near Point San Pedro, and on sandstone at Pescadero Point, 50 feet above the ocean. Not common.

Lecanora bolanderi Tuck. Proc. Am. Acad. 6: 266. 1864; Syn. N. Am. Lich. 1: 181. 1882.

2. LECANORA THAMNITIS Tuck.

"Thallus papillate-fruticulose, made up of short, erect, fastigiately divided trunks which are crowded densely together into an effuse crust (or pass now into compact, rounded peltate clumps); pale straw-colored; apothecia middling to ample, sub-terminal; disk from pale-yellowish passing into tawny-red, margin crenate. Spores ovoid-ellipsoid, $\frac{10-14}{6-8}$ mic." Lich. Calif. p. 20.

"Sandstones of the Pacific coast; Oakland hills, and S. Bruno (Bolander), Tuckerman, l. c. 1866." Tuckerman, Synopsis N. Am. Lichens, Part I, p. 181; 1882.

San Bruno, mentioned above, is in San Mateo county and the lichen should occur with us but thus far I have been unable to discover it. Tuckerman states that it is probably but a form of *L. bolanderi*.

Lecanora thamnitis Tuck. Lich. Calif. 20. 1866; Syn. N. Am. Lich. 1: 182. 1882.

3. LECANORA PHRYGANITIS Tuck.

Thallus short, terete, rigid; simple or irregularly short-branched; tufted, or forming low, rounded, intertangled mat-like clumps, the branches longer and decumbent at the circumference; covered with yellowish gray-green granules or powder; beneath brown or blackening basally; apothecia not seen, all our specimens being sterile. Tuckerman states, Syn. N. Am. Lich. Vol. I, p. 182: "apothecia middling to ample, lateral, sub-sessile; disk pale-brick-colored, margin flexuously lobed; spores oblong, ellipsoid, $\frac{12-16}{5-7}$ mic."

Abundant on granite cliffs above the sea near Point San

Pedro, at an altitude of 300 feet. A few plants also found on sandstone at Pescadero Point, at an elevation of 50 feet.

A very distinct lichen, always associated with *Lecanora pinguis* Tuck., and *L. bolanderi* Tuck.

Lecanora phryganitis Tuck. Lich. Calif. 19. 1866; Syn. N. Am. Lich. 1: 182. 1882.

XIX. **Cladonia** (Hill) Wainio.

Thallus 2-fold; the primary one usually inconspicuous, of horizontal or up-turned, more or less leafy squamules or merely granular; the secondary one more conspicuous, forming the "plant," of upright hollow podetia, which may be simple and club-, cup- or funnel-shaped, or shrub-like and much branched; apothecia cephaloid, red or brown, borne on the tips of the podetia; spores ovoid-oblong, simple, colorless, small, very much alike in all the species.

The species of *Cladonia* are comparatively few in number, but are of wide distribution and within certain limits are greatly variable. The boundaries of some of the species are therefore difficult to define, but all the members of the genus are readily recognizable as *Cladonias*.

An almost indefinite number of varieties, sub-varieties, and forms have been described, and what one author has described another has recast and subdivided until great confusion is the result.

From a single handful plucked from a thick mat of some *Cladonia* one may isolate a dozen of the named varieties of certain authors, until as a result one has a separate name for almost every individual in the lot. This, it seems to me, is the *reductio ad absurdum* of classification.

That all differing forms should be segregated is self-evident, but to give a name and a description to every individual variation is to make a farce of systematic botanical or zoölogical work, while to take no account of the plasticity of organisms and their consequent yielding to the varying environmental conditions is to shut one's eyes to the larger phases of scientific work.

In the present paper the material has been described in accordance with the determinations of Dr. Zahlbruckner, but the account here presented is only tentative. Before the *Cladonias* of the region can be understood a full collection of determined material must be at hand for purposes of comparison with local material.

Cladonia Hill, His. Pl. 91. 1751; in part.
Cladonia Wainio, Monog. Clad. Univ. 1887.

KEY TO THE SPECIES.

a. Apothecia scarlet; podetia powdery or granular..9. *macilenta*, 391.
aa. Apothecia brown.
b. Not cup-bearing; podetia irregularly branched.
c. Podetia stout, cæspitose, club-shaped, densely clad with leafy squamules....................................7. *squamosa*, 390.
cc. Podetia slender, fruticose, subulate; branches spreading, curved, much divided..... ....8. *furcata racemosa*, 391.
bb. Podetia cup-bearing; simple.
d. Cups proliferous.
e. From the center..............................6. *verticillata*, 390.
ee. From the margins of the much reduced cups. 2. *chlorophæa prolifera*, 388.
dd. Cups not proliferous.
f. Podetia turbinate, with cyathiform cups.
g. Podetia longitudinally furrowed..1. *pyxidata costata*, 387.
gg. Podetia not longitudinally furrowed: epidermis of yellowish or sulphur-colored powder..2. *chlorophæa*, 388.
ff. Podetia cylindrical, trumpet- or club-shaped; cups reduced, often obsolete.
h. Podetia stout, short, roughened and verrucose or even squamulose...............5. *fimbriata tubæformis*, 389.
hh. Podetia powdery; not roughened.
i. Podetia stout, trumpet- or club-shaped; tips obscurely cup-like................... 3. *fimbriata clavata*, 389.
ii. Podetia slender, filiform, pointed, to coarse and blunt, with greatly reduced cups..4. *fimbriata cornuta*, 389.

1. CLADONIA PYXIDATA COSTATA Floerke.

Primary thallus of minute to medium-sized ascendant squamules, entire or crenate-lobate; rarely large: color sage-green to brown. Podetia short, stout, turbinate, with longitudinal furrows; basally more or less warty or sub-squamulose; above more or less naked; cups dilated, with margins more or less denticulate or proliferous; within usually granular warty or even squamulose; apothecia small, brown.

On earth and rock, at an elevation of about 1000 feet, on the Page Mill road, Black Mountain.

Probably not uncommon in the mountains above 1000 feet.

Cladonia pyxidata is a very variable species; the variety *costata* is distinguished from the typical form of the species by the podetia being longitudinally furrowed and more or less naked.

Cladonia pyxidata costata Floerke, Clad. Comm. 66. 1828.

2. CLADONIA CHLOROPHÆA Floerke.

Squamules of primary thallus crenate-lobed, rather broad, medium size to large; usually ascendant; green to ashy or olive brown. Podetia simple, short, broadly turbinate, rising from center of squamules; covered with a yellowish-greenish or sulphur-colored powder, or warty granules; cups dilated, rather deep, with entire or denticulate margins. Apothecia rare, brown, becoming confluent.

Occurring throughout on earth and stumps.

2a. CLADONIA CHLOROPHÆA PROLIFERA Arn.

Podetia elongated and comparatively slender; cups but little evident, their margins greatly extended in branched proliferations; these flattened or expanded and more or less densely clothed with leafy thalline lobules; summits terminated by the abundant, minute, light brown apothecia.

A peculiar form resembling *Cladonia squamosa* in the abundant squamules on the thallus, and in habit and general appearance like a very stout and coarse condition of *Cladonia furcata racemosa*. "Habet podetia scyphosa qua *C. furcata* non habet," Zahlbruckner *in litt.*

On earth in the redwoods above Woodside, at an altitude of 1200 feet.

Cenomyce chlorophæa Floerke, in Somm. Suppl. Lapp. 130. 1826.

Cladonia chlorophæa Floerke, Clad. 70. 1828.

3. CLADONIA FIMBRIATA CLAVATA Arn.

Primary thallus of leafy, rounded, very numerous and imbricate squamules, more or less ascendant, passing finally into an effuse, powdery crust; margin crenate or incised, upturned; color brown, varying from pale whitish or brownish green to dark; margin usually paler; beneath white. Podetia ascendant from surface of primary squamules, simple, stout, cylindrical, trumpet- or club-shaped, the tips obscurely cup-like, with more or less denticulate margin, or more usually blunt or pointed; thickly covered with a greenish or whitish powder. Apothecia rare, small, terminal, or on the denticulate margin of the cups; becoming confluent and larger; very dark brown.

A common lichen on rotton wood, earth and moss; occasional on old roofs. Generally distributed throughout the peninsula.

Cladonia fimbriata clavata Arnold. Act. Soc. Faun. Fl. Fenn. 10: 293. 1894.

4. CLADONIA FIMBRIATA CORNUTA (L.) Acharius.

Primary thallus of leafy, elongate squamules, more or less lobed, with crenate or laciniate margins; color pale or dull sage-green; beneath very white. Podetia rising from surface of squamules; simple, small to medium, slender, terete; apically pointed and thread-like; or coarser, thicker, blunt, with greatly reduced, minutely denticulate cups; more or less thickly covered with a greenish powder, through which the white cortex is more or less visible. Apothecia very minute, brown, on tips of denticulation of cups.

On dead wood, rotten logs, and old roofs. I have specimens from the roof of a house in Mayfield, at an altitude of about 35 feet, and from logs of *Sequoia sempervirens* in the hills above Wright's Station, at from 1200 to 1500 feet altitude. Probably occurring throughout our range wherever redwoods are native.

Lichen cornutus L. Sp. Pl. 2: 1152. 1753.

Cladonia fimbriata cornuta Ach. Syn. Meth. Lich. 257. 1814,

5. CLADONIA FIMBRIATA TUBÆFORMIS Hoffm.

Primary thallus densely imbricate, squamulose. Podetia short, stout, broadly trumpet-shaped; covered with a greenish powder, becoming rough and verrucose; occasionally with thalline squamules; cups entire or denticulate; tips of the teeth capped by the very minute dark brown apothecia.

Collected on an old roof in Mayfield, at an altitude of 35 feet. Probably occurring throughout the foothills and mountains, on old dead wood.

Cladonia pyxidata tubæformis Hoffm. Deutsch. Fl. 2: 122. 1791.

6. CLADONIA VERTICILLATA Hoffm.

Primary thallus leafy, rounded or more or less dissected, usually crenate-lobulate; brownish green, whitish beneath.

Podetia cylindrical, from short to elongated, cup-bearing; the cups marginally denticulate and 2–5 times proliferous from their center, forming a series of whorls; sometimes two or more branches arise from one cup. Podetia smooth, but here and there roughened or bearing occasional thalline lobules. Color gray-green to brownish.

Apothecia light to dark brown, on short stalks from margin of cups, or nearly sessile on margins.

(Forma *phyllophora* Floerke differs in the much greater development and elongation of the primary thallus, which may be as much as an inch in length in the larger and frequently leafy cups, and the often conspicuous and abundant thalline leaflets on the podetia, especially on the basal joints. The podetia are also longer and proportionately slenderer.)

On earth and in crevices of rocks. Found throughout the foothills and mountains. Ofttimes growing in the dryest situations on the rocky summits of hills, where even the chaparral is thin and stunted.

Cladonia verticillata Hoffm. Deutsch. Fl. 2: 122. 1795.

7. CLADONIA SQUAMOSA (Scop.) Hoffm.

Primary thallus leafy or squamulose, lobulate or dissected.

Podetia erect, cæspitose, 1½ to 3½ inches long, irregularly much-branched, forming matted clumps; densely clothed to the summit with light green or brown squamules, these often large, leafy and lobulate; epidermis pale green, disappearing, the surface then pale reddish brown; axils of branches sometimes inflated, their tips usually subulate. Apothecia numerous, very small, clustered, dark brown.

On earth on damp hillsides.

Not rare in the foothills at moderate elevations.

Lichen squamosus Scopoli, Flora Carniolica ed. 2. 2: 368. 1772.
Cladonia squamosa Hoffm. Deutsch. Fl. 2: 125. 1795.

8. CLADONIA FURCATA RACEMOSA (Hoffm.) Floerke.

Primary thallus at first of tiny scattered squamules, these eventually quite long, leafy, lobed, with crenate-lobulate margin; pale green. Podetia fruticose, very slender, elongated; branches spreading, curved, intricately divided; surface smooth, becoming more or less roughened or thickly clothed with squamules or thalline lobules; axils of branches often gaping; tips of branches very slender and subulate, or thickened and stumpy. Color varying from a very pale greenish gray to brown. Apothecia numerous, very small, pale to dark brown. On earth in the foothills; not rare. My best specimens are from Pilarcitos Creek Cañon, two miles from the Pacific, at an altitude of 200–300 feet.

Cladonia racemosa Hoffm. Deutsch. Fl. 2: 144. 1795.
Cladonia furcata racemosa Floerke, Clad. Comm. 152. 1828.

9. CLADONIA MACILENTA (Hoffm.) Nylander.

Primary thallus minute to small, squamulose or leafy, scanty, crenate-lobate; pale gray-green to brownish; white beneath. Podetia cylindrical, slender or sometimes swollen, simple, or with few and irregular branches; occasionally dilated at the summit and forming cups, these marginally proliferous with (usually) fertile branchlets; covered by a pale gray-green powder or by granules, these becoming squamules and on the lower half finally leafy lobules, similar in form and color to those of the primary thallus; the white ground color usually but little evident; specimens occasionally occur in which the powder or granules are not present. Apothecia scarlet, turning black when wet; small to medium, irregular, more or less confluent; terminal.

On stumps and old logs of *Sequoia sempervirens* and *Pseudotsuga taxifolia*.

A common, handsome and somewhat variable Cladonia.

Cladonia macilenta Hoffm. Deutsch. Fl. 2 : 126. 1795.

Cladonia macilenta Nylander, Syn. Meth. Lich. 223. 1860.

XX. **Dendrographa** Darbish.

Thallus fruticose, erect or decumbent, tufted or matted; filaments terete or compressed basally, branched, with infrequent lateral soredia; color gray. Alga *Trentepohlia* (*Chroolepus*). Apothecia lateral, circular, the disk black, white pruinose; spores quadrilocular, colorless, spindle-shaped or slightly curved.

On maritime shrubs on coast of California or on earth and rocks in the same region.

Dendrographa Darbishire, Ber. der Deutsch. Bot. Gesellsch., 13: 313. 1895; Darbishire, Monographia Roccelleorum (Bibliotheca Botanica, 45). 1898.

1. DENDROGRAPHA MINOR (Tuck.) Darbish.

Thallus fruticose, erect or more often lax and decumbent, tufted; terete and hair-like or slightly flattened below, much and intricately branched, forming dense, tangled clumps; color gray, or basally blackening. Sterile. Large globose lateral soredia sparingly present.

Abundant on rocks and earth 50–100 feet above the sea near Golden Gate, San Francisco. As yet not found elsewhere within our limits.

Roccella leucophæa var. *minor* Tuck.,

Dendrographa minor Darbishire, Ber. der. Deutsch. Botan. Gesellsch. 16: 13. 1898.

XXI. **Sphærophorus** Pers.

Thallus fruticose, erect, shrub-like, rather rigid, much branched; medulla densely cottony. Tips of the fertile branches swollen, enclosing the globose apothecia; spores simple, spherical, violet-black.

But one species occurs in our territory.

Sphærophorus Persoon, in Usteri Annal. d. Bot. 1 : 23. 1794.

1. SPHÆROPHORUS GLOBOSUS (Huds.).

Thallus fruticose, tufted and shrub-like, erect, branched, terete, smooth, with short, fine, and very numerous terminal branchlets, these often in clumps which shatter off very readily; color silvery gray or whitish but varying to brownish or a decided brown; rarely reddish. Alike on all sides. Medullary layer densely cottony. Apothecia terminal, within the swollen and globular tips of the fertile branches, which split open exposing the globose apothecia; spores violet-black, simple, spherical.

On trees, dead wood, and sandstone. On the Pacific side of the peninsula occurring from near sea-level to the summit of the range, but not descending on the Bay side more than a few hundred feet, remaining within the limits of the spruce and redwood forests. Occasionally found in great abundance. A handsome and striking looking plant.

Lichen globosus Hudson, Fl. Anglica, vol. 1, 460. 1762.
Lichen globiferus L. Mantissa 133. 1767.
Sphærophorus globiferus DeCandolle, Fl. Fr. 3d ed. 1805.
Sphærophoron coralloides Persoon, Usteri Annal. d. Bot. 1: 23. 1794.

XXII. **Dermatocarpon** (Eschw.) Th. Fr.

Thallus foliaceous or squamulose, umbilicate or appressed and adnate. Apothecia very small, immersed, appearing as minute specks on the surface; spores ellipsoid or ovoid, simple, colorless, usually 8 in the obsolete paraphyses.

On rocks and earth.

Our squamulose forms not included in the present paper.

Dermatocarpon Eschweiler, Syst. Lich. 16. 1824; in part. Th. Fries, Genera, 103. 1861.

KEY TO THE SPECIES.

a. One-leaved, large ....1. *miniatum*, 394.
aa. More or less polyphyllous.
  b. Thallus more or less cæspitose, the convolute and complicate lobes ascendant................2. *miniatum complicatum*, 394.
  bb. Thallus pseudo-crustaceous, small, closely appressed. 3. *aquaticum*, 394.

1. DERMATOCARPON MINIATUM (L.) Mann.

Thallus medium to large, smooth, coriaceous, one-leaved or lobate, the margin rounded, undulate or crenate, and more or less recurved; attached by an umbilicus: color whitish to bluish gray or occasionally brownish; sometimes granulose pruinose; beneath varying from a bright to a dark brown or black; smooth or minutely pustulate. Apothecia very numerous, minute, scattered, immersed in the thallus; opening by small dark or brown pores, which appear as specks thickly distributed over the entire surface. Spores simple, colorless, ellipsoid.

On rocks, in shaded or damp situations.

A common and conspicuous lichen throughout the foothills and to the summit of the Santa Cruz range, the thallus reaching a diameter of more than two inches.

Lichen miniatus L. Sp. Pl. 2: 1149. 1753.
Dermatocarpon miniatum Mann.

2. DERMATOCARPON MINIATUM COMPLICATUM (Sw.).

Thallus small to medium, polyphyllous, densely compacted, the imbricate and complicate lobes rotund, convolute and more or less ascendant, with recurved margin; the surface more or less roughened and wrinkled. Otherwise like the species.

Common in the foothills with the species.

Lichen complicatus Swartz, Nova Act. Upsal. 4: 38. 1776.
Dermatocarpon miniatum complicatum.

3. DERMATOCARPON AQUATICUM (Weis.).

Thallus small, thick, smooth, lobes densely imbricate and compacted; margin rounded, entire or crenate-lobulate: closely appressed, umbilicate; resembling an intricately convolute, adnate, crustaceous lichen: color dull gray or olive-brown; sometimes white granulose pruinose; beneath dark brown to dingy black; smooth. Apothecia as in *Dermatocarpon miniatum*, but proportionately larger and less numerous.

Abundant on granite cliffs 200 feet above the sea, near Point San Pedro. Occurring also on wet sandstone in Devils Cañon, altitude 2300 feet.

Lichen aquaticus Weis, Pl. Crypt. 77. 1772.
Dermatocarpon aquaticum.

INDEX TO LICHEN PAPER.

NOTE. — New species and subspecies in **black face** type.

INDEX

NOTE.—New names in **black-face type**, synonyms in *italics*.